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THE SCIENTIFIC MONTHLY

DECEMBER, 1916

WHAT WE KNOW ABOUT COMETS[1]

By Dr. W. W. CAMPBELL

DIRECTOR OF THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA

THE startlingly sudden appearance of some great comets, the rapid growth of others to enormous sizes and their equally rapid disappearance have naturally excited the interest and, only too often, the fears of the human race. We are removed less than two centuries from the long-prevailing theological view that comets are flaming fire-balls hurled at the earth by an angry God, to frighten and punish a sinful world. Up to the time of my childhood the opinion was widespread among civilized peoples that comets are the forerunners of famine, pestilence and war. Did not the great comet of 1811 herald the war of 1812; the comet of 1843 the war of 1846; and Donati's comet of 1858 our Civil War? Even in the twentieth century the fear that a comet may collide with the earth and destroy its inhabitants comes to the surface, here and there, every time a comet is visible to the naked eye. This fear is not lessened by the highly sensational descriptions of such encounters by professional writers who have that little knowledge which has been called a dangerous thing.

The earth has undoubtedly encountered comets' tails scores and scores of times since the advent of man, and with no baneful effects; and in the light of present-day knowledge of the structure and chemical composition of comets there is no danger whatever that our atmosphere will be poisoned by such an encounter. It is true that a collision between the earth and the head of a comet *could* happen, but we see no reason to question the accuracy of the estimates made by mathematical astronomers that such encounters will not occur more than once in fifteen or twenty million years, on the average! It is by no means certain that such an encounter, should one ever occur, would be a serious matter for the earth. Its effects might be confined to a brilliant shower of meteors, such as the peoples of the earth have observed many times. Geologists are of the opinion that the outcropping strata

[1] Retiring address of the first president of the Pacific Division of the American Association for the Advancement of Science. San Diego, August 9, 1916.

of the earth which they have been able to study have required a period of approximately 100 million years for their formation. These strata, embracing the entire land area of the earth, have given only one bit of evidence that the earth's surface has been affected by a collision with an outside body. In central Arizona is a cup-shaped hole-in-the-ground, about three quarters of a mile in diameter and several hundred feet deep which has been formed, with little doubt, by the descent of a great meteorite, or of a great cluster of small meteorites: thousands of small iron meteorites have been found in and around the hole, and there are no evidences of volcanic activity in the neighborhood. Geologic and geographic surveys of the earth have revealed no other case of collisional effects[2] in the records of a hundred million years. Man himself has lived upon the earth certainly many tens of thousands of years, and there are no traditions extant concerning injuries to earth or to man from comets. Why then should anybody worry about possible injury from a comet in his short span of three score years and ten?

The answer to our first question, where do comets come from, involves the question of their relationship to the solar system and to the great stellar system. It is essential that every auditor should understand certain prominent features of the solar and stellar systems; and, at the risk of repeating what many members of the audience already know, I shall devote a few lines to a description of these systems.

Widely scattered throughout a great, but finite, volume of space occupied by our stellar system are tens of millions of stars. It is estimated that our largest refracting telescopes could show us about seventy million stars, and that the reflecting telescopes could photograph possibly two or three times as many. Our own sun is just one of these scores of millions of stars. It seems very large, very bright and very hot because we on the earth are relatively close to it. It is our own star. Revolving around it are many planets, of which our earth is one. Probably the other stars in many cases, possibly in all cases, have planets revolving around them in the same way. We do not know that this is a fact because the nearest star, excepting our own star, is so far away that we should require telescopes at least twenty-five feet in diameter to see planets revolving about it, even though such planets be as large as Jupiter and Saturn, the largest planets revolving around the sun.

Now the sun and its planets and their moons are the chief members of an orderly system which we call the solar system. Ninety-nine and six sevenths per cent. of all the materials in the solar system is in the sun, and only one seventh of one per cent. is divided up to form the planets and their moons: Mercury, Venus, the Earth and its one moon, Mars and its two moons, the more than 800 minor planets which move

[2] Neglecting the insignificant cavities produced by isolated small meteorites.

in the zone lying just outside the orbit of Mars, the giant planet Jupiter and its nine moons, the planet Saturn with its ring system and its nine moons, the planet Uranus and its four moons, and the outermost-known planet Neptune and its one moon.

It is a most interesting fact that all of these planets revolve around the sun in the same direction, which astronomers have agreed to call from west to east, or in the "direct" sense. Motion from east to west is called "retrograde."

Another remarkable fact is this: the orbits of all these bodies lie nearly in the same plane. If we call the distance from the sun to the earth unity, then the distance from the sun to the outermost planet, Neptune, on the same scale is thirty units, and the diameter of the solar system on that scale is sixty units. If we had a great box sixty such units in diameter and only one unit in thickness the solar system could be placed within this box and all of the eight major planets and their moons and nearly all of the minor planets would perform their motions within the box. A few of the minor planets would dip a little out of the box, above or below.

The solar system is very completely isolated in space. If the distance from the sun to the earth is one and from the sun to Neptune thirty, then the distance to the next nearest star of which we have any knowledge, Alpha Centauri, is 275,000. A ray of light traveling with a speed of 186,000 miles per second would travel from the sun to the earth in eight and one third minutes, to Neptune in four and a half hours, but it would require four and a half years to reach the sun's nearest neighbor, Alpha Centauri. The stars in the great stellar system are distributed more or less irregularly, but their average distance apart is of the order of six or seven or eight light years.

All of the stars are in motion, and our own star, the sun, is no exception to the rule. It is one of the well-established facts of astronomy that our solar system is traveling through space in the general direction of the boundary line between the constellations Lyra and Hercules with a speed of approximately twelve and one half miles per second.

It is well known that the orbits of our planets are ellipses which do not differ greatly from the circular form. The comets, on the other hand, move in very elongated orbits around the sun. The orbits of some comets are easily recognized as ellipses, but for the great majority of comets the orbits differ but little from the parabolic form. The parabola, as many of you know, is on the dividing line between ellipses and hyperbolas. The ellipse is a closed curve, and a comet moving around the sun in an elliptic orbit should return again and again to the neighborhood of the sun; but a comet following a parabolic or hyperbolic path, subject merely to the attraction of the sun, can pass through the vicinity of the sun only once, for the parabola and hyper-

bola are not closed curves, and the branch upon which the comet approaches the sun and the branch upon which the comet recedes from the sun never come together, no matter how far out from the sun they be drawn.

There have been two hypotheses as to where the comets come from. Sir Isaac Newton thought of them as moving in elongated ellipses. It

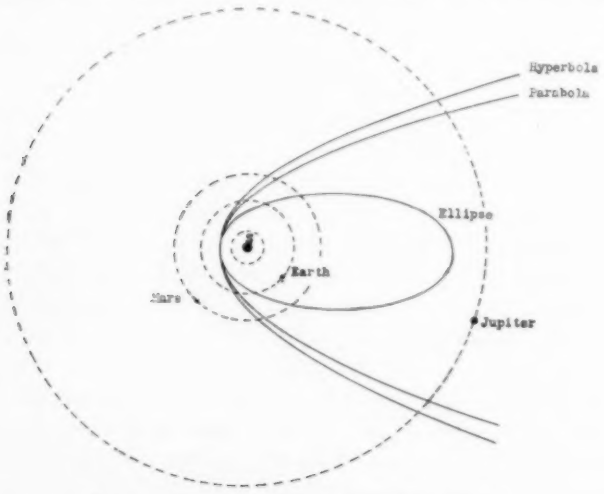

FIG. 1. CHARACTERISTIC FORMS OF ORBITS.

was the view of Immanuel Kant 160 years ago that comets are bona fide members of the solar system, just as the earth and Neptune are: that their orbits are all ellipses, but very elongated ellipses. He said that the comets travel out a great distance from the sun, but that they must eventually return because they are moving in ellipses. Kant's view of the subject was essentially a mere opinion, though the opinion of one of the greatest philosophers of all time, who gave careful consideration to every known fact. Up to Kant's day, and for many decades later, comet observations were crude in comparison with present-day standards. Most comets were observed for only a few weeks, and the true characters of their orbits could not be affirmed.

Half a century later the great Laplace championed the view that the comets belong to the stellar system and not to the solar system; that comets are travellers through interstellar space; that the wanderings of a chance few comets bring them within the sphere of influence of our sun; and that we see those which come into favorable position near the earth. Halley's celebrated comet was the only one then known to return again and again to the region of the sun, and it was thought to be a captured wanderer. In Laplace's time also the comets were still inaccurately observed, over short periods of time, and in nearly

every case a parabola seemed to represent their motion satisfactorily. This Laplacean view that comets are wanderers through the great stellar system and are only chance visitors to the solar system was the prevailing one throughout the nineteenth century. Evidences to the contrary began to appear as early as 1860, but so firmly rooted was the hypothesis that only in the twentieth century have astronomers in general been convinced that the comets are members of the solar system. Several lines of evidence, all in good agreement, have brought us to this conclusion.

1. Since the solar system is traveling through the stellar system in the direction of the constellations Lyra and Hercules, with a speed of twelve and a half miles per second, if comets come in from interstellar space we should *meet* more comets coming from the Lyra-Hercules direction than there are comets *overtaking* us from the opposite part of the sky, for precisely the same reason that if we are traveling very rapidly by automobile from San Diego to Los Angeles we should meet more autos than would overtake us and pass us. Now the comets do not show that preference. As early as 1860 Carrington studied the directions of approach of all the comets, 133 in number, which up to that time were considered to have parabolic or hyperbolic orbits. He found that only sixty-one[2] of these comets met the solar system, so to speak, whereas seventy-two[2] comets overtook us—extremely strong evidence that the comets are traveling along with us, just as all of our planets are traveling with the sun while revolving around it. Many later astronomers, especially Fabry, using the more plentiful and more accurate data now available, have confirmed this conclusion that there is no tendency for comets to meet us, as we rush through interstellar space, rather than to overtake us. It is a fact, however, that the observed comets have not had their directions of approach distributed uniformly over the surface of the sphere. Their deviations from reasonable uniformity appear to be due in small measure to a preference of comets to travel in planes making small angles with the ecliptic, with motion around the sun from west to east as in the case of the planets; but the chief discrepancies arise from the heterogeneous circumstances under which comets are discovered.

Nearly all discoveries of comets made by means of telescopes prior to forty years ago were made in the northern hemisphere, at observatories situated in latitudes north of $+40°$. The southern hemisphere is still very much in arrears in the matter of comet discoveries, though the discrepancy is not now so great as it once was.

There is more searching for comets in the northern hemisphere during the northern summer and in the southern hemisphere during the southern summer than in their respective winters. There is also

[2] The disparity in the numbers is thought to be purely accidental.

a better chance for northern observers to discover comets when the sun is farthest north in June and for southern observers when the sun is farthest south in December. These facts lead to the discovery of comets, prevailingly, which come to perihelion in certain favored regions; that is, in the regions of the sky where the earth is at those times.

It is advantageous at this point to call attention to other sources of lack of homogeneity in comet data.

Prior to the invention of the telescope, three centuries ago, about 400 comets had been made matters of historical record. These were naked-eye objects which forced themselves upon the attention of observers. They were the especially large comets which came close to the earth or to the sun. They were imperfectly observed, and for only a small proportion of them do we know even their approximate orbits.

Since the invention of the telescope, about 450 comets have been discovered, and the half of these have been found in the last fifty years. What we may call the golden age of comet discovery included the two decades, 1888 to 1908, when 100 comets, an average of five per year, were discovered. Four American observers, Swift, Brooks, Barnard and Perrine, announced the arrival of thirty-seven of these 100 comets.

All of the early comets were visible to the naked eye. Only a small fraction of recent comets, perhaps one in four, become bright enough for the unassisted eye to see the head, and perhaps one in eight or ten for the unassisted eye to see the tail. Comet orbits have become increasingly accurate, partly because of greater telescopes, which enable these bodies to be more accurately observed and observed through longer arcs of their orbits.

2. Another decisive argument for the theory that comets are at home in the solar system is this: Schiaparelli showed in the early '70's that, owing to the sun's motion through the stellar system, if the comets come from distant interstellar space, a very large proportion of them should move around our sun in hyperbolic orbits, and many of these orbits should be *strongly* hyperbolic. Schiaparelli's conclusions have been confirmed and extended by several mathematical astronomers, notably by Louis Fabry. Fabry concluded: If the sun travels through the stellar system and the comets come to the sun from interstellar space, then the comets should all move in hyperbolas—differing from the parabola the more as the velocity of the sun through space is the greater.

What are the facts of observation? Of 347 comet orbits fairly well determined

(*a*) 60 are certainly elliptic;
(*b*) 275 are approximately parabolic;

(*c*) 12 or fewer are slightly hyperbolic;

(*d*) None are strongly hyperbolic.

Now it has been shown by Thraen, Fayet and Fabry in the last two decades that several of the twelve orbits thought to be hyperbolic were not really so, but that they owed their reputations to poor or insufficient observations, or to errors in the computations, and that all of the genuine hyperbolas save one acquired their hyperbolicity after the comets concerned came under the disturbing influences of our planets. Five years ago Strömgren was able to show that the one outstanding hyperbolic orbit was caused, in the same way, by the disturbing attractions of the planets. The original, undisturbed orbit of every one of the so-called hyperbolic comets was, therefore, an ellipse. Fayet has further shown that a very great majority of the orbits which had been observed to be sensibly parabolic when the comets were near the planets and sun were clearly elliptic when the comets were still far out from the sun; that is, as these comets, moving in elliptic orbits, came in toward the planets and sun, the attractions of the planets made their orbits approach closely to the parabolic form. There is no reason to doubt that far out in the domain of the sun the comets all approach in elliptic orbits; but that when the attractions of one or more of our planets upon them become appreciable, some of the orbits are changed into shorter ellipses, others are changed into ellipses so long that it is difficult to distinguish them from parabolas, and many orbits are changed to the hyperbolic form. Those comets whose orbits are thus thrown into the hyperbolic form will leave the solar system and travel out through the stellar system.

3. A statistical study of comet orbits made by Leuschner a decade ago bears upon this question. He found that prior to 1755 ninety-nine per cent. of all comets were *said* to move in parabolic orbits, but that only fifty-four per cent. of comets between 1846 and 1895 were *said* to move in orbits approximately parabolic; and, secondly, that of comets under observation less than 100 days, sixty-eight per cent. were *said* to be parabolas, whereas of those observed from eight months to seventeen months, only thirteen per cent. have orbits approximately parabolic. These facts point to the conclusion that when comets are observed inaccurately, as of old, and in only a short section of their orbits, parabolic orbits satisfy the observations within the limits of the errors unavoidably attaching to those observations; but that when comets are observed accurately and for a long stretch of time, nearly all are found to be moving in ellipses. Most of the ellipses are of course extremely long ones.

If comets starting substantially at rest came from a very great distance away from our sun, say one hundredth the distance of the nearest star, which we think is decidedly within the sphere of our sun's attrac-

tion, they would move in ellipses so elongated that we could not hope to distinguish them from parabolas. Their periods of revolution would be nearly one hundred and fifty thousand years. Yet they would be members of our solar system, subject to the sun's attraction, and unless disturbed by some other body or bodies, they would return again and again to the center of the system.

The work of Carrington, Schiaparelli, Fabry, Fayet, Strömgren and Leuschner and of many others has left no room for doubt that comets are bona fide members of our solar system. The materials composing the great majority of comets spend most of their time in regions far removed from the sun and its planets, as our little distances in the planetary system go, but close to the sun in terms of the magnificent distances which separate our sun from the other suns. They are moving in closed orbits around our sun and traveling through space along with our sun.[4]

Besides the comets which go out on extremely elongated orbits to great distances from the sun, there are about fifty elliptic comets which

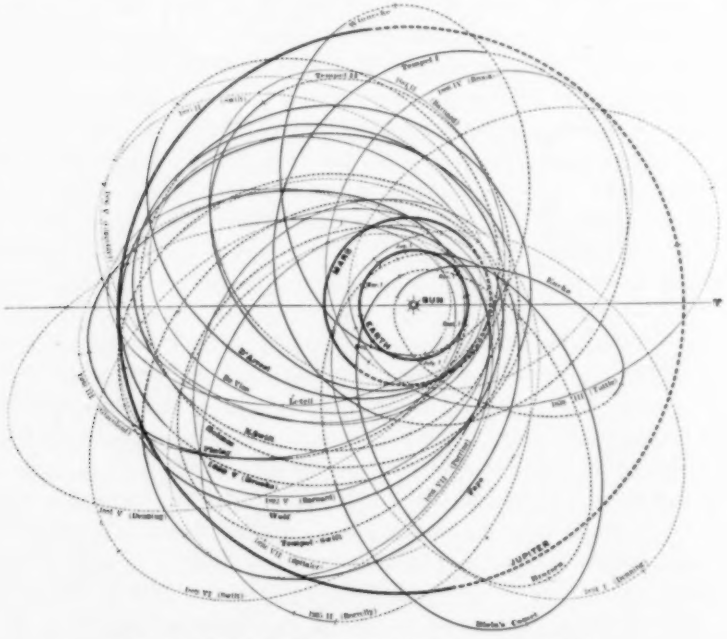

FIG. 2. JUPITER'S FAMILY OF COMETS (up to 1893).

[4] Those who would like to look more thoroughly into this question are strongly advised to read Schiaparelli's paper on "Orbites cométaires, Courants cosmiques, Météorites," in Bulletin Astronomique, vol. 27, pp. 194–205 and 241–254, 1910. It embodies some points of view slightly different from those presented by me. The technical contributions by Fabry, Fayet and Strömgren are extensive and of a high order of merit; and students of comets cannot afford to neglect them.—W. W. C.

are closely related in one sense to some of our planets. About three dozen are in the so-called Jupiter-family of comets. The orbits of all those discovered up to 1893 are represented in Fig. 2. It is seen that the outer parts of all of them—the aphelia—are in the vicinity of Jupiter's orbit. Similarly, there are a few comets related to Saturn's orbit, a few to the orbit of Uranus, and six comets to the orbit of Neptune, one of the latter being Halley's comet. The Jupiter comets have periods lying between three and nine years, and the Neptune comets complete their circuits in from sixty to eighty-one years.

What has been the history of these short-period comets? H. A. Newton and other investigators have shown that it would be impossible for great numbers of comets, such as have been observed, to move through the solar system, without a certain proportion having their orbits changed into short-period elliptic orbits. It is the accepted view that the short-period comets have been captured, so to speak, by the combined attractions of the sun and one of the planets in each case. The chances of capture by the planets are greatest when the approaching bodies are moving in orbits which lie in planes most nearly coincident with the plane of the planetary system, and when their motions around the sun are from west to east. Newton's analysis of the problem led to the conclusion that five or six times as many captured comets should move in the direct sense, west to east, as in the retrograde sense, east to west. Now the only comets with periods less than 100 years which are revolving around the sun in the retrograde direction are Halley's comet, period seventy-six years, and comet 1866I, period thirty-three years. The three dozen members of the Jupiter family revolve from west to east without exception. That the motion in the short-period orbits is so universally from west to east finds the most probable explanation in the view that the cometary materials, when they were farthest from the sun, long before they approached the region of the planets and the sun, already had a slow motion from west to east, the motion of the parent mass of matter from which the solar system itself was developed. The French astronomer, Faye, on the assumption that comets have originated in the outer parts of a rotating mass which has developed into the solar system, came to the conclusion that comets should move prevailingly in the direct sense when their orbit planes do not differ greatly from the orbit planes of the planets, but that those whose orbit planes make great angles with the plane of the solar system should show no preference for the direct over the retrograde motions. These theoretical results are in good accord with the observed facts.

Our second question is, what are comets?

Comets have certain characteristic features:

1. There is always a head, or coma as it is sometimes called, a shin-

FIG. 3. HALLEY'S COMET, MAY 1, 1910; head and beginning of tail.

ing mass of hazy, nebulous matter. The head is sometimes circular in outline, more frequently elliptical or nearly so, but again it is oval on the edge facing the sun and it merges insensibly into the tail on the side opposite the sun (Figs. 3, 4 and 5). The sizes of comet heads vary enormously. One less than 10,000 miles in diameter would be most unusual and generally would escape discovery. The head of the great comet of 1811 was at one time more than a million miles in diameter. The head of the great comet of 1882, which many of us

enjoyed seeing, was for a long time about 150,000 miles in diameter. It is a curious fact that the heads of comets in general contract in size as they approach the sun and expand as they recede from the sun. Encke's periodic comet, which has been observed on many returns, frequently had a diameter of 250,000 miles or more when the comet was at a great distance from the sun, whereas the diameter of the head reduced to 10,000 or 15,000 miles when the comet was nearest the sun.

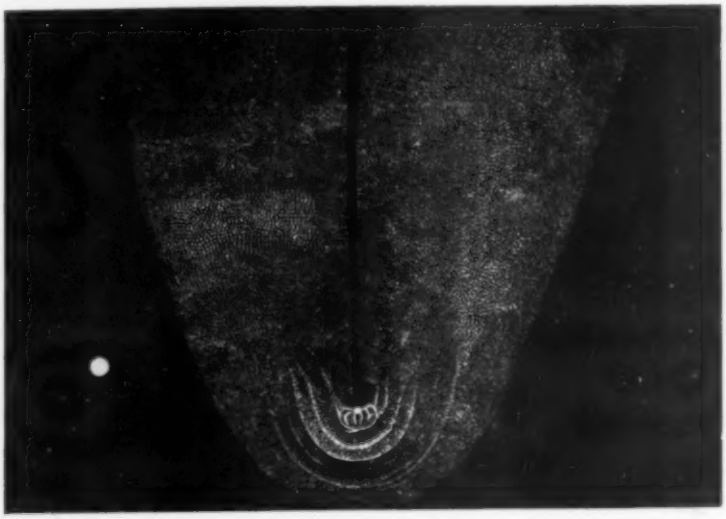

FIG. 4. DONATI'S COMET, 1858 OCTOBER 5: head and beginning of tail; brilliant stellar nucleus near center of head; envelopes surrounding nucleus on side toward the Sun. White circle to the left represents comparative size of the Earth.

Before the disappearance into distant space the head resumed its original dimensions. A satisfactory explanation of the contraction and expansion of the heads of comets has not been found.

2. Near the center of the head of the comet there is usually a brilliant, star-like point which we call the nucleus (Fig. 4). This is the point upon which accurate measures are made when it is a question of determining the position and the orbit of the comet. In general the nuclei are most sharply defined for those comets which have come in from great distances upon orbits nearly parabolic, and the nuclei are frequently hazy, poorly defined, and sometimes entirely lacking, in the comets composing Jupiter's comet family. Occasionally there is a double, a triple, or a quadruple nucleus, a division undoubtedly connected with the disintegration or breaking up of the comet into smaller masses. The size of the nucleus varies greatly, apparently from a few miles up to several thousand miles in diameter.

3. Most comets have tails. They frequently develop to enormous

dimensions. When a comet is observed at a great distance from the sun, only the head and nucleus are usually visible. The tail develops with close approach to the sun. The tail of the comet of 1882 was at one time more than 100 million miles in length; that of 1843 was at one time 200 million miles. As comets recede from the sun, the tails diminish in extent and usually disappear long before the head and nucleus are lost to sight. Several of the Jupiter comets do not have

FIG. 5. HOLMES'S COMET OF 1892; no tail was visible in the telescope; long-exposure photographs (Barnard, 3 hours, 1892 Nov. 10) recorded an extremely faint tail extending down to lower right corner of the picture. The great spiral nebula in Andromeda was recorded on the photograph—upper left corner of picture.

visible tails (Fig. 5). They appear not to possess in abundance the materials which go to form comets' tails.

4. When comets approach relatively close to the sun the heads frequently throw off a series of concentric shells or envelopes. The materials composing these envelopes appear to be expelled from the head and toward the sun at high speed, but these speeds of approach to the sun seem to be gradually overcome and the materials turned away from the sun to assist in forming the tails (Fig. 4).

The tails of comets, it is well known, point away from the sun. However, the popular view that they point *exactly* away from the sun is seriously in error. In general they lag behind the line passing through the sun and the comet's head (Fig. 6). There can be no doubt that they point away from the sun because of some repulsive force, originating in the sun, which acts upon the minute dust particles or gas molecules released from the comet's head. It takes time for these particles to travel out millions of miles from the head, and,

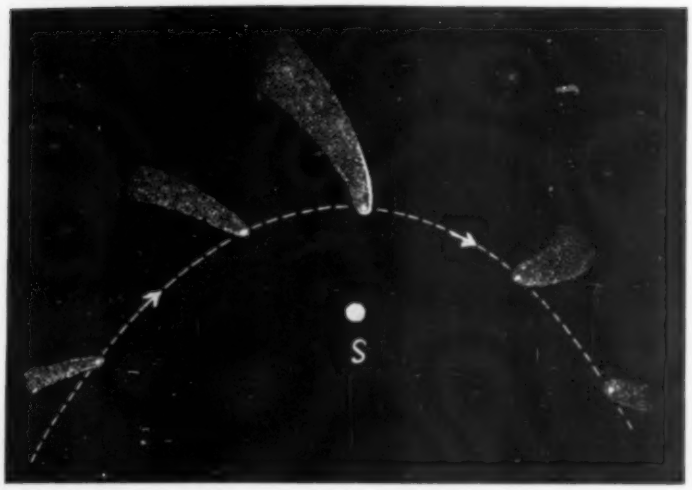

FIG. 6. COMETS' TAILS LAG BEHIND THE LINE JOINING THE SUN (S) AND THE COMETS' NUCLEI. Orbital motion is carrying the nucleus of the comet to the right.

while they are moving out, the head is moving forward in its orbit. The nucleus obeys the gravitational attraction of the sun absolutely, so far as observation has gone, and we have no reason to suspect that it is subject to an appreciable repulsive force.

The particles composing the outer regions of the head and the particles composing the tail are doubtless attracted by the gravitation of the sun and are at the same time driven away by the repulsion of the sun. What the particles will do under the action of the two opposing forces depends upon the ratio of these forces. If the repulsive force is vastly stronger than the attracting force the particles will travel out from the head with great and increasing speed and form a tail pointing nearly away from the sun; that is, it will lag behind very little. If the attracting and repelling forces acting upon another group of particles are not very unequal those particles will form a second tail having considerable lag. If the repulsive force is very weak with reference to the sun's attractive force upon a third group of particles, they will form a short tail that lags very far behind. The forms and

FIG. 7. DIAGRAM ILLUSTRATING THE THREE PRINCIPAL TYPES OF TAILS OF COMETS. Orbital motion is carrying the nucleus to the left. The Sun is below.

positions of comet tails were studied extensively by Bredichin, who found that there were three classes of tails, corresponding to three fairly definite ratios of repulsive to attractive forces, as indicated by three different degrees of lagging behind the line joining the sun and the head (Fig. 7).

Bredichin determined that the long slender tails, observed in a few comets, which lag behind only slightly are the result of a repulsive force twelve to fifteen times as intense as the attractive force. He found another class of comet tails, of medium lag, for which the repulsive forces were from 2.2 to 0.5 times the attractive forces. Another class of tails, short and bushy, with very strong lag, were explainable on the assumption that the repulsive forces were relatively weak, from 0.3 to 0.1 of the attractive forces.

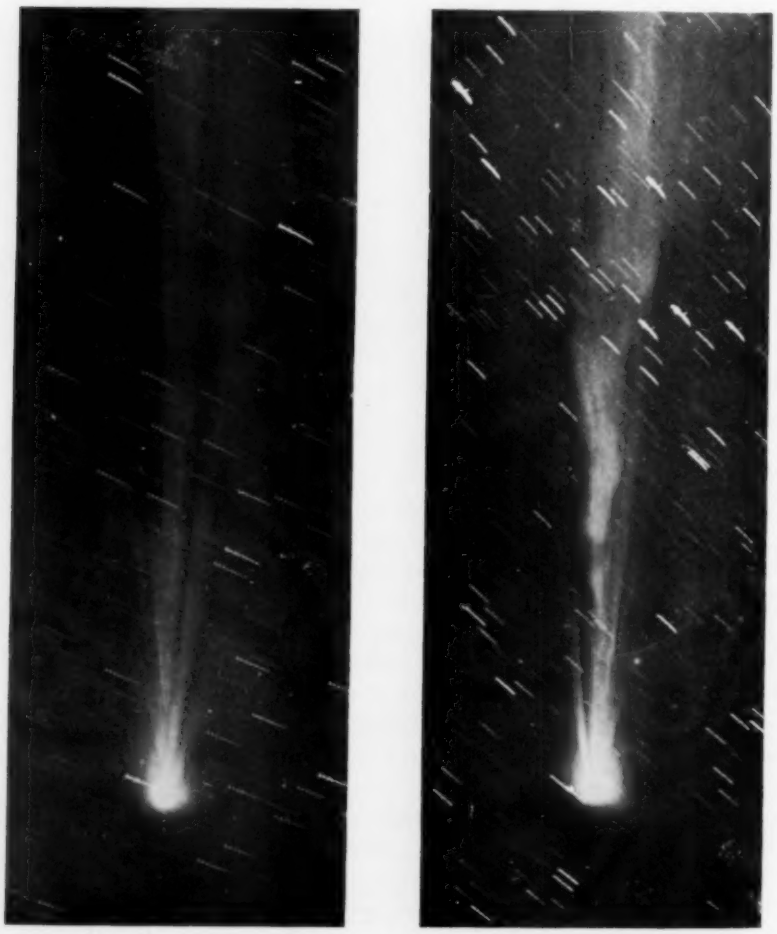

FIG. 8. COMET RORDAME ON JULY 12 AND JULY 13, 1893. The camera followed the nucleus of the comet and the stars "trailed."

In some comets only one of these three classes of tails is present, and again in one and the same comet all of the classes may be present at the same time.

That there is outward motion of the tail materials admits of no doubt. It is not uncommon for the tail materials of one night to be driven off into space, scattered and lost to sight, and for an entirely

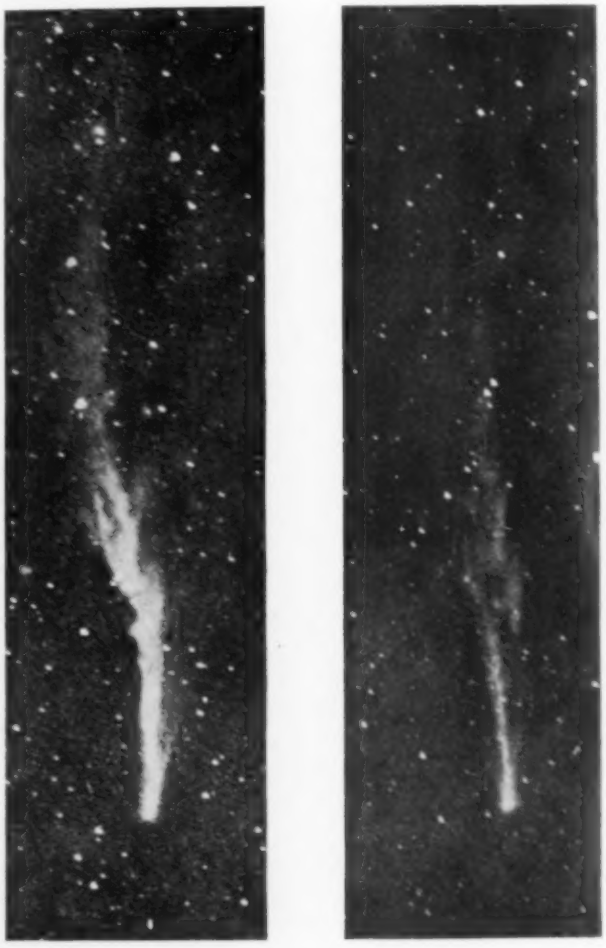

FIG. 9. COMET BROOKS ON OCTOBER 21 AND OCTOBER 22, 1893.

new tail to take its place by the following night. A comet's tail is constantly forming and moving out. The tails of comet Rordame (Fig. 8) photographed by Hussey on two successive nights, July 12 and 13, 1893, have no points of resemblance. The streamers composing the tail on one night are fairly straight, regular, and rather faint. The

tail of the following night is very much broken, there are several fairly well-defined nuclei, and it is brighter than the tail of the twelfth. Two photographs of this comet were fortunately made on the second night, with a time interval of three quarters of an hour. A comparison of the positions of the three nuclei on the two plates showed that they had moved outward from the head with great speed during the interval. The nucleus nearest the head had traveled out with a speed of forty-four miles per second, the next nucleus with a speed of fifty-two miles a second, and the one still farther out with a speed of fifty-nine miles per second. Here are two photographs of comet Brooks (Fig. 9) made on October 21 and October 22, 1893, by Barnard. The structure of the tail on the first photograph is not at all the structure on the second. The tail of the first night has been scattered to invisibility and an absolutely new tail has replaced it. The outward motion of well-defined tail structure has been measured for many comets. Here is a series of measures made by Curtis upon points in the tails of Halley's comet.

AVERAGE VELOCITIES OF RECESSION, FROM THE HEAD, OF MATTER IN THE TAIL OF HALLEY'S COMET

Date, 1910	Mean Distance from Head	Average Velocity
May 23	800 miles	0.6 miles per sec.
May 27–28	400,000 miles	8 miles per sec.
May 25–26	930,000 miles	12 miles per sec.
June 2–3	1,360,000 miles	20 miles per sec.
May 28–29	1,730,000 miles	23 miles per sec.
June 6	2,200,000 miles	27 miles per sec.
May 26–27	2,500,000 miles	24 miles per sec.
May 30–31	6,600,000 miles	45 miles per sec.
June 7–8	8,400,000 miles	57 miles per sec.

The points to be measured were not well defined, and the measures could not be accurate, but it is clear that high speeds and accelerated speeds prevailed. The tail materials start out slowly from the head, and increase their speeds with the distance from the head, as we should expect of motion resulting from the action of a continuous force which meets with no sensible resistance.

In Fig. 10 are reproductions of photographs of Halley's Comet made by Curtis on June 6 and June 7, 1910. A semi-detached part of the tail, seen on the photograph of June 6 about an inch above the head, is visible about two and a half inches above the head on the photograph of June 7. This structure was first observed by Curtis shortly after it had emerged from the central part of the head on June 4, and it was recorded on the photographs secured by a great many observatories in the following four days, as the rotation of the earth carried the comet successively into position for observation at the observatories. The times when the lower point of the structure had certain positions is

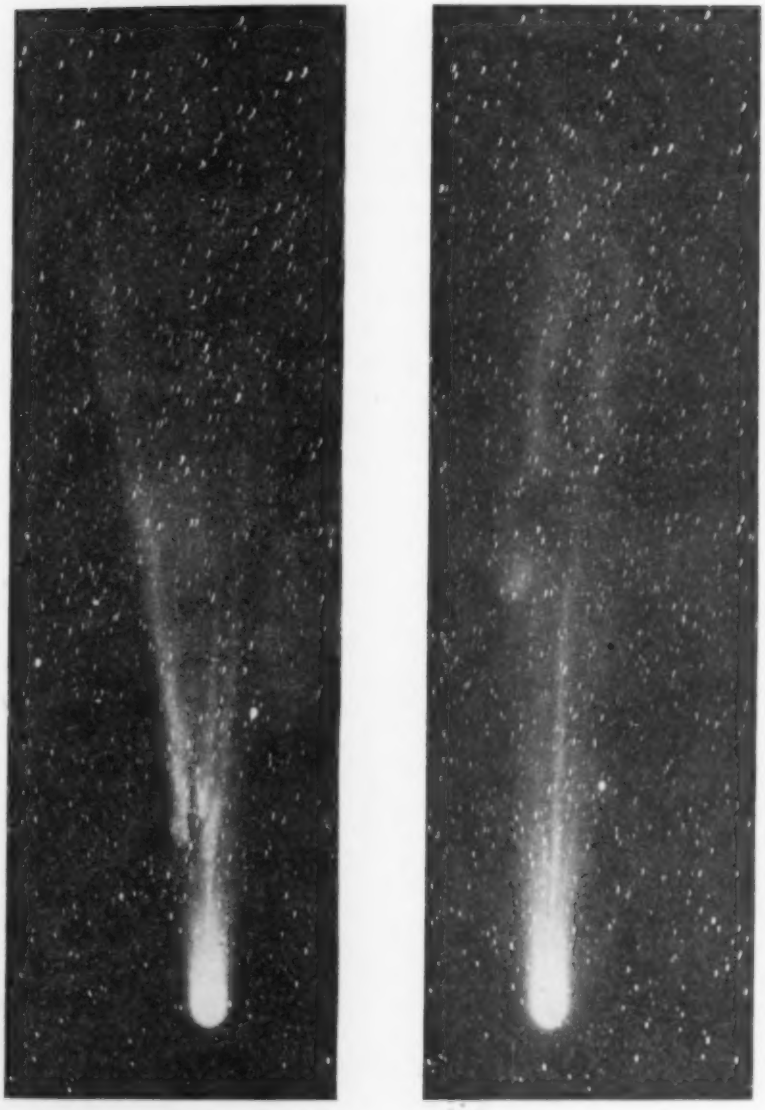

FIG. 10. HALLEY'S COMET, JUNE 6 AND JUNE 7, 1910.

indicated in Fig. 11. The tail did not seem to lag behind the position of the radius vector—the line passing through the sun and the comet's nucleus—because the observers on those days were nearly in the plane of the comet's orbit and the lag of the tail was toward the observers. The velocity with which the structure moved out in the tail was strongly accelerated with the passing of time, as may be seen from the chart.

The constant loss of materials dispelled along the tail would seem to require that comets in general grow fainter with time. This is the logical conclusion, and the observational evidence for it is undoubted in many of those comets which return again and again to the region of the sun. Nearly all of the Jupiter comets have a hazy, washed-out appearance. Several of them do not develop tails, as if their supply of tail materials had already been exhausted by expulsion as former tails. Others of them develop only very short tails, and several short-period comets have entirely disappeared. To this phase of the subject we shall return.

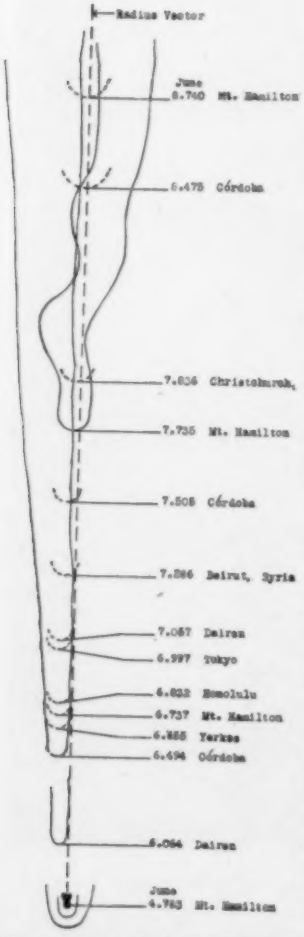

FIG. 11. SUCCESSIVE POSITIONS OF THE INNER END OF A DETACHED TAIL OF HALLEY'S COMET, JUNE 4–8, 1910.

As to the nature of the repulsive force responsible for comets' tails: It was long thought to be electrical, arising from a strong electrical field about the sun and from electric charges of the same sign on the particles composing the tail. The idea is in part purely speculative, but the giving of serious consideration to it is justified because of the fact that much of the light of comets seems to arise from electrical conditions in them. The idea may be wrong in toto, or an electric repulsive force may be one of two or more forces which are acting. It can hardly be the only force involved.

Clerk-Maxwell half a century ago, from pure theory, and Lebedew and Nichols and Hull some fifteen years ago, from experimental evidence admitting of no doubt, showed that when light energy falls upon a surface it presses against that surface; very feebly it is true, but it will cause the body pressed upon to move if that body is not too massive. In this respect light-pressure repulsion and electric repulsion should act much alike. These repulsions are effective in proportion to the surface areas of the bodies acted upon, whereas gravitation pulls those bodies with a force proportional to their masses. Now the surface of a body is proportional to the square of its dimensions, whereas gravity acts in proportion to the cube of its dimensions. The smaller a body is the more surface it has in proportion to

its mass. Electric and radiation-pressure repulsions will therefore act more efficiently upon very small particles than upon large ones. A cube of water one centimeter on each edge would be drawn by the sun's gravitational action 10,000 times as strongly as the pressure of the sun's rays falling upon that body would repel it. But a cube of water only 1/1000 of a mm. on each edge would be in equilibrium under the sun's gravitational attraction and the sun's light-pressure repulsion. A cube of water less than 1/1000 mm. would actually be driven rapidly away from the sun. The equilibrium diameter for little spheres of water, according to Nichols and Hull, is .0015 mm. Now as light energy is traveling along with a speed of 186,000 miles a second, we should expect particles of matter considerably smaller than the equilibrium size to travel away from the sun with great and rapidly increasing speeds. These speeds would be the greater for particles smaller and smaller until a certain limit of size with reference to wave-length of light is reached, after which the light would be diffracted without transmitting so large a proportion of its repulsive energy to the particles. These limits of efficiency were determined by the lamented Schwarzschild. The resistance of cometary particles is evidently also a function of the specific gravity of the particles. The figures which we have quoted are for water, density 1. We can scarcely doubt that radiation pressure is an important force, perhaps the chief force, perhaps the only force responsible for the driving out of the materials of comets' tails. Particles of solid matter or gas molecules of three different classes of sizes might be responsible for the three main classes of comets' tails. More probably materials of three different classes of density compose the three classes of tails. Bredichin called these three classes the hydrogen, the hydrocarbon and the iron tails. The atomic weights of these three substances give to their atoms or molecules about the right mobility, under equal pressure upon all, to explain the lags of the three classes of tails. Unfortunately it is far from certain that hydrogen exists in comets, and iron has been reported for only one comet.

The hoods or envelopes (Fig. 4) which form the outer strata of the heads of comets which come close to the sun are very interesting. It is the prevailing view that, when a comet approaches the sun, the solar heat falling upon that surface of the comet which faces the sun generates or liberates the gases and vapors which have been contained in or between the more solid parts of the comet; and being liberated, in effect, under pressure, the materials at first travel toward the sun with considerable speed. The sun's repulsive force acts upon these jets and, overcoming the forward motion of the materials, it eventually turns them back along the tail. Those phenomena have been observed many times.

There is a great variety of comet spectra, indicating as great a variety of cometary contents or conditions. In some cases the spectrum seems almost wholly continuous, as in Holmes's comet of 1892; in others the light when passed through the spectroscope falls almost wholly into isolated bright lines or bands, as in Morehouse's comet of 1908. Other spectra are a combination of continuous and bright-line light (Fig. 12). The spectrum of the nucleus seems to be always continuous, or continuous except for absorption lines. In some of the brighter comets the nucleus spectrum as photographed contains the well-known absorption lines visible in the sun's spectrum. These observations indicate that the nucleus is shining, at least mainly, by reflected sunlight. In most comets the continuous spectrum is too faint to let us photograph it and thus to prove the presence or absence of the solar absorption lines. The continuous spectrum in many

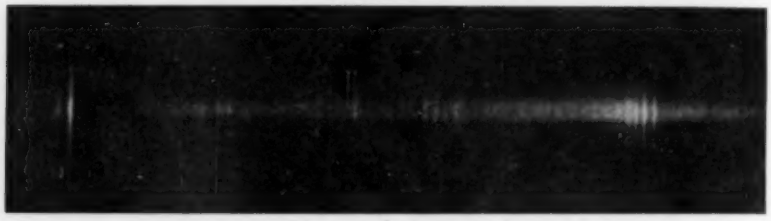

FIG. 12. SPECTRUM OF COMET DANIELS, 1907.

comets extends also to the head, or at least to the inner strata of the head. This may or may not mean reflected sunlight. It may mean some other form of luminescence which yields a continuous spectrum. The greater parts of the heads of comets and those parts of the tails of comets which are close to the heads nearly always, and perhaps in every case, give a characteristic spectrum of bright bands, which were for several decades called the hydrocarbon bands. Observations of recent years have made it probable that this spectrum does not indicate a combination of hydrogen and carbon, but that it is either one of the low-pressure carbon vapor bands or that it results from one of the compounds of carbon and oxygen, preferably from carbon monoxide. The lines and bands of cyanogen—a nitrogen compound—and of carbon are present without any question in the heads and inner tails of many comets. Several observers have reported that the so-called hydrocarbon spectrum of the heads and inner tails extends far out into the tails. This may have been true for the cases reported, but recent observations are casting doubt upon the presence of that spectrum in the outer extensions of comet tails. Improved methods of photographing comet spectra were applied to the bright comets, Daniels of 1907 and Morehouse of 1908, especially by Deslandres, Evershed and Chrétien,

with the result that their tail spectra were proved to be very different from the prevailing spectra of comets' heads and inner tails. Fowler has succeeded in duplicating the tail spectra of these two comets, in his laboratory, with remarkable agreement (Fig. 13), by photographing a cathode spectrum of carbon monoxide in a tube reduced to pressure not exceeding .01 mm. At higher pressures than this he obtained the so-called hydrocarbon spectrum, but it was not certain, and in fact it was improbable, that there was any hydrogen in the tube. The presence of carbon and nitrogen in comets is certain, the presence of oxygen is probable, and the presence of hydrogen is doubtful.

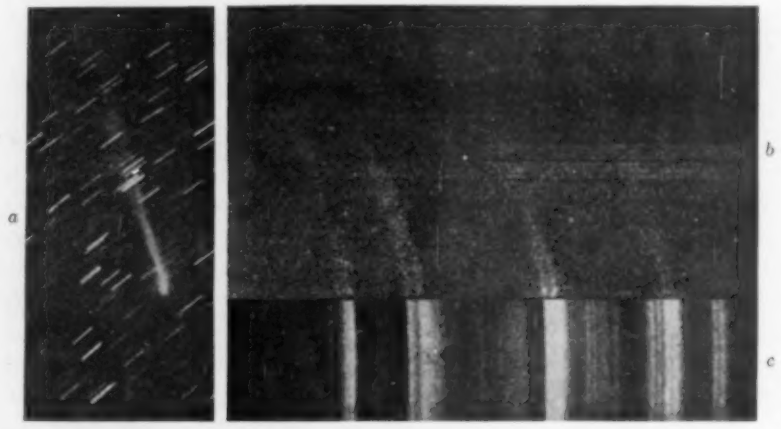

FIG. 13. (*a*) Ordinary photograph of Comet Morehouse. (*b*) Spectrum photograph of Comet Morehouse made at same time as (*a*). (*c*) Fowler's spectrum of carbon monoxide, whose principal bands match the principal spectrum images of the comet's tail.

The comets which have approached very close to the sun turned to a yellowish orange in color and remained so while in the vicinity of the sun, because the yellow light of sodium then developed strongly in them, apparently by virtue of the intense heating of the cometary matter by the sun's rays. This happened with the Wells comet of 1882, the great comet of September and October, 1882, the brilliant comet in January, 1910, and others. When the September, 1882, comet was only a few hundred thousand miles from the sun, Copeland and Lohse observed not only the sodium lines but half a dozen other bright lines which they concluded were well-known iron lines.

What is the origin of the light which gives bright lines and bands? The sodium lines certainly, and the iron lines if actually observed, were no doubt due to incandescent vapors of those elements under the intense heat of the sun. Strangely enough, when the sodium comets approached the sun, the carbon bands, which had previously been promi-

nent, disappeared entirely and remained invisible until the comets had receded to a considerable distance from the sun and the sodium lines were no longer in evidence. The carbon light could scarcely be generated by heat action, for if so the carbon bands should have been in evidence during the time that the comet was passing nearest to the sun. Much more probably the bright-line spectra of the head and tail are of electrical origin, or fluorescent. This phase of the subject is technical, and to some extent speculative, and we can not profitably pursue it further on this occasion.

A certain proportion of the light of many comets is slightly polarized. The interpretation of this phenomenon is that a fraction of the light of the heads and of the inner tails of comets is sunlight diffracted by minute dust particles or gas molecules in the comet structure.

Returning to the subject of the disintegration and disappearance of comets:

A small comet was discovered by Montaigne in 1772. A comet was discovered by Pons in 1805. A comet was discovered by Biela in 1826. Biela computed the orbit of his comet and found it to be moving in an ellipse of period six and a half years, and he proved that the three comets discovered respectively by Montaigne, Pons and himself were identically the same comet. Biela's comet was rediscovered in 1832, almost precisely in its expected place. The next return was missed because the body was not in good position for observing. It was rediscovered in 1845, when it was seen to consist of two comets moving side by side on orbits almost identical. In 1852 both comets were reobserved, but farther separated than they had been in 1845. The comet was searched for at the proper times for several later returns, but it was never seen again.[5]

Kirkwood published in 1872 a list of eight comets which had divided in a similar manner and disappeared.

A number of other comets have completely disappeared, though their orbits were very well determined.

This brings us to another interesting phase of our subject:

The Perseid meteors are with us at this time of the year. Many of them have been seen every year for several decades. They are usually most numerous on the nights of August 9, 10 and 11. Predictions concerning meteors are somewhat risky, but so faithfully have the Perseids come every August that I have no doubt an observer to-night, to-morrow night and the next night, from midnight on to daylight, would see dozens of meteors whose paths traced backwards would pass through a small area in the constellation of Perseus. In 1866 Schiaparelli computed the orbit of the Perseid meteors and noticed that it

[5] One of the components of the Biela comet may have been observed for a few hours from Madras in 1872.

was essentially identical with the orbit of Comet 1862III. Here are the elements of the two orbits.

Orbits of	Meteors of August 9, 10, 11	Comet 1862III
Perihelion passage	July 23.62	August 22.9
Longitude of perihelion	343° 38′	344° 41′
Ascending node	138 16	137 27
Inclination	63 3	66 25
Perihelion distance	0.9643	0.9626
Period of revolution	105 years?	123.4
Direction of motion	retrograde	retrograde

The difference in the two perihelion times does not mean that their orbits were different even to the minutest degree, but only that, moving on the *same* orbit, they reached the point nearest the sun at slightly different times; that is, one of the bodies traveled over the orbit a little in advance of the other. The revolution period assigned to the meteors is subject to considerable error because it is not possible to observe the paths of the meteors with great accuracy.

There were rich and startling showers of meteors on November 12, 1799, and on November 12–13, 1833. H. A. Newton examined the literature of meteoric falls and found that many similar showers had been observed at intervals of thirty-three years running back several centuries, to 902 A.D., "the year of the stars," and he confidently predicted that another great shower would occur on November 13–14, 1866. His prediction was abundantly verified. Early in 1867 Schiaparelli and Le Verrier independently computed the orbit of these meteors, and Schiaparelli and Oppolzer independently found it identical with the orbit of the comet 1866I. Here are the elements of the two orbits:

Orbits of	Meteors of November 13	Comet 1866I
Perihelion passage	November 10.092	January 11.160
Longitude of perihelion	56° 25′.9	60° 28′.0
Ascending node	231 28 .2	231 26 .1
Inclination	17 44 .5	17 18 .1
Perihelion distance	0.9873	0.9765
Eccentricity	0.9046	0.9054
Semi-major axis	10.340	10.324
Period of revolution	33.250 years	33.176 years
Direction of motion	retrograde	retrograde

It is impossible to doubt that these November meteors and the comet referred to were traveling in the same orbit.

The so-called Lyra meteors are visible about April 20 each year. It was noticed in 1867 by Weiss that the orbit of the Lyra meteors is essentially identical with that of the comet 1861I.

Biela's comet, to which we have referred, when last seen in 1852, as a double comet, was expected to return in 1866 and again in 1872, but it was not seen then, nor later. A meteor shower of moderate intensity was observed on November 27, 1872, moving in the orbit of the lost comet.

Not to dwell upon the remarkable identities of the orbits of the four meteor swarms, respectively, with the orbits of the four comets (Fig. 14), two of which have disappeared, and the other two, of relatively long periods, which may never return, we express the prevailing opinion of astronomers in saying that the meteor streams have actually resulted from the disintegration of the four comets. Alexander Herschel has prepared a list of seventy-six meteor streams whose orbits agree fairly closely with seventy-six comet orbits. A certain proportion of the suspected identities probably represent facts. It is inter-

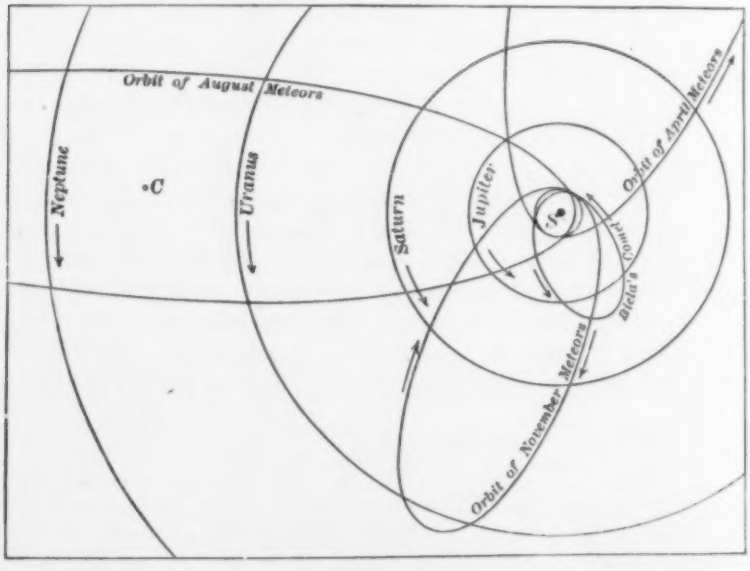

FIG. 14. ORBITS OF METEORIC SWARMS, which are known to be associated with comets.

esting to note that even as early as 1861 the truth of the situation was expressed and printed by Kirkwood:

> May not our periodic meteors be the debris of ancient but now disintegrated comets whose material has become distributed around their orbits?

It was in this connection and at that time that Kirkwood was able to make a list of eight comets, each of which had divided into two or more parts and had wholly disappeared from the sight of observers.

The cause of the disintegration of comets is not far to seek. A

comet's nucleus is thought to be a collection or cluster of small bodies, such as have been observed to collide with our atmosphere and to produce the meteor showers. They are held together, so to speak, while they are far away from the sun, because of their own very small but sufficient attraction for each other; but when they come within our planetary system, and especially when they come relatively close to the great planets Jupiter and Saturn, the sun and the planets attract the nearer particles of the comets more strongly than they do the farther particles. The nearer particles forge ahead on smaller orbits, the farther particles lag behind on larger orbits, and in the course of centuries the cometary material is strewn along a great stretch of the orbit. Other separative forces—of magnetic or electric natures, for example—may develop amongst the particles composing the nucleus as a comet approaches the sun. The intensity of the reflected light in all parts of the scattered comet structure becomes too small to let us see the remains of the comet, except as the remnants collide with the earth's atmosphere. There is certainly no reason to doubt that a very great many of our shooting stars are the remains of disintegrated comets. Tens of millions of little meteors enter our atmosphere every twenty-four hours and with rare exceptions are consumed by the heat of friction with the atmosphere when they rush through it at tremendous speeds. The gases from the combustion enter the atmosphere, and the ash and other unconsumed parts fall down to the earth's surface in due time. Accumulated meteoric dust is found in the perpetual snows at the tops of high mountains, and Sir John Murray found it in the ooze brought up from the depths of the oceans. Whether the meteorites which penetrate our atmosphere and are found and placed in our museums are parts of ancient comets can not safely be asserted, but it seems entirely possible that some of them are. However, it is not certain that any meteorite found on the earth has come from a meteor stream of recognized cometary origin. It is pretty well established that many of the sporadic meteors which plunge into our atmosphere were traveling on hyperbolic orbits.

We discover only a certain proportion of the comets which come close to the sun and to the earth. The numbers which course through the planetary system and remain undiscovered by the observers on the earth must be exceedingly great. The supply of cometary material in the remote outskirts of the planetary system must be enormous. This material is probably in the nature of remnants of the nebula or other mass of matter from which the sun, its planets and their moons developed. This idea is to a certain extent speculative; but that the cometary material is now out there in abundance we can not doubt. Much of it naturally consists of matter in the solid state; and, the sun's attraction at that great distance being almost zero, neighboring masses

could slowly come together as a collection of small solid masses, such as seem to compose the nucleus of a comet. Such a nucleus could attract and attach to itself any dust particles and molecules coming within its sphere of attraction. These might well, and probably would, include a collection of finely divided matter that had already been driven off in the tails of comets which in earlier ages had visited the sun. The materials thus collected would be attracted by the sun, a few of the collections would eventually pass comparatively close to the sun, a few of the latter would be discovered as comets, and a part of the finely divided material contained in them would be driven off again as comets' tails into space, possibly to return many times in the bodies of comets coming later into the sun's neighborhood. Certain of these bodies would come so close to the planets as to have their orbits transformed from very long ellipses to very short ellipses. These comets would be disintegrated and their materials be widely scattered. We have seen that the earth ha collided with such materials, and the earth is growing slowly, very slowly, through the deposition of the remains upon its surface. Probably a little of the same materials goes likewise to other planets of the solar system and adds slowly to their masses. However, an insignificant proportion of the materials scattered in this manner through the solar system is thus accounted for, and the remainder doubtless revolves around the sun in ellipses, probably contributing its share of reflected sunlight to the faint glow near the sun known as the zodiacal light.

We have seen that devoted students of comets have learned much concerning these interesting travelers. Many mysteries have been removed, but many questions remain for the astronomers of the future to answer. We should especially like to know more of the physical conditions existing in comets, more about their chemical contents, and more as to why and how they shine by their own light. Perhaps the most valuable result of cometary investigation has been the emancipation of civilized peoples from unreasoning and groundless fears of these bodies, which come and go in obedience to the same simple laws that govern our every-day affairs.

THE STRATEGICS OF SCIENTIFIC INVESTIGATION

By Professor T. BRAILSFORD ROBERTSON
UNIVERSITY OF CALIFORNIA

The thirty spokes unite in one nave; but it is upon the space for the axle that the use of the wheel depends.—Lâo-Tsze.

IN all ages and among all races since man first made his début upon our earthly stage, certain individuals have differed from their fellows in the possession in unusual measure of impersonal curiosity combined with powers of observation, comparison and generalization. Where historic record fails we can infer the existence of these individuals from the heritage of knowledge which they conferred upon their descendants. Such knowledge did not come to man by revelation, or rather, let us say, the revelations of past ages did not differ in kind from those of our own time. The mental exertions which led to the development of the stone axe from the fortuitously encountered sharp fragment of flint did not differ in kind, possibly not even in degree, from those which led to the development of the aeroplane from a Chinese toy.

These individuals, whom I prefer to call investigators, avoiding alike the barbarism of the word "researcher" and the restricted connotations of the word "scientist," have but rarely, at any stage of the world's history, appeared of any importance in the eyes of the acknowledged rulers and leaders of mankind. In so far as they have occasionally combined charlatanry with science, as in the case of the ancient or medieval astrologers or a certain type of modern inventor, they have, it is true, occasionally achieved notoriety and the consequence attaching to the recipients of the beneficent toleration of rulers. In times of actual and impending disaster the desperate ruler not infrequently turned to his men of contemplation, to his astrologer, his magi or to Archimedes, with the helpless confidence with which the stricken patient turns to the surgeon upon whose labors he has never bestowed a thought in his days of health. History repeats itself, because the politicians and financiers of to-day are merely protean forms of the satraps and merchants of Persia, or the senators and bankers of old Rome placed in a different material setting, and the parallel between the European governments of to-day turning desperately to science for aid in the extremity of their peril and the Oriental emperor who in a like pass appealed to his wise men who were versed in the stars, would be comic indeed, were it not so unutterably tragic.

It has been but rarely, and then wholly fortuitously, that the investigator has been valued as a potent factor in society. In those rare instances it has been the individual who was valued, not the type, and the value has generally been that which the collector places upon a unique item in his collection, or which the vaudeville artist places upon his performing panther, or that vague and fruitless veneration with which the sage, the hermit or the dear old unpractical sweetly-disposed rector of an English village is not unfrequently regarded—veneration which arouses no desire of emulation, but which finds its source in the incomprehensibility of the inspiring motive or its remoteness from the commonplace.

It has not infrequently been recognized by rulers that the patronage of learning has occasionally been rewarded by unexpected benefits, and from Hiero relying upon Archimedes for the defence of Syracuse to Christina of Sweden summoning Descartes to read to her before breakfast, rulers have sporadically contributed to the service of investigation. In modern times likewise it is officially recognized that the investigator may be an ornament to the state, but, save in the times of stress aforesaid, no hint of consciousness is betrayed that the labors of the investigator may constitute the very framework of civilization.

"Old women for old women," says Walpole, referring to the Royal Society, "I would trust to the analysis of the matrons in preference to that of the philosophers."[1] When the master-investigator of all time, Michael Faraday, ventured, in response to the ill-advised persuasion of his friends, to apply to government for a minute fraction of the recognition to which his incalculable services had entitled him, he was received by Lord Melbourne with the epithet "humbug." In 1914 when one of the greatest medical investigators of our day preferred a similar request to government his plea was received by the official overlords with the silent contempt of utter indifference.[2]

The mental attitude of the general public towards the investigator is similar to, but less financially profitable than, the attitude of tolerant and half-contemptuous admiration which is displayed towards the artist and the virtuoso, and it would be alike endurable were it not fraught with the very gravest dangers. What confidence would we possess in the lawyer unaware of the sources of common law or in the doctor who was professedly ignorant of the anatomy and physiology of the human body? What confidence shall we then display in the statesmen who remain oblivious and blind to the nature of the formative forces which under their very eyes are continually refashioning civilization? A momentary recognition of the danger of ignoring the investigator is,

[1] "An Account of the Giants Lately Discovered," 1766; Works of Horatio Walpole, 1798, Vol. 2.

[2] Cf. correspondence in the *Morning Post* and other London newspapers in the spring of 1914.

it is true, being displayed throughout the civilized world at present, owing to the crucial part which his labors play in the organized destruction of life and property which is the chief preoccupation of civilized peoples at this date. Good resolutions are being actively formed in Great Britain, America, Canada and Australia, resolutions which find expression in governmental plans for the future administration of scientific research. The education and training of the professional politician is, however, so purely legal, commercial and, in rare instances, literary, that it is not a matter for surprise that the various schemes for the furtherance of research which have thus amiably been put forward betray little comprehension of the real needs and potentialities of the investigator and little or no grasp of his true significance in world politics. Indeed the various plans which have been proposed will, if they materialize, carry with them very real dangers to true research and were the investigator as stridently vocal as the politician, I think it not unlikely that in many quarters at the present juncture earnest appeals might be heard from the scientific investigator to be saved from his friends and to be favored once more with the obscurity to which, like certain fish which dwell in caves, he has become by habitude adapted.

The various plans to which I have made allusion all bear indeed the unmistakable stamp of the mental bias of the political administrator. They unite in assuming that any given problem can be solved provided only the requisite number of persons, duly provided with diplomas, be paid to investigate it under the supervision of course of the omniscient administrator, who, in some of the plans I have instanced, is not even required himself to take part in the labors of his employees. Such tactics are well known to succeed in the production of public buildings, and while it may well be doubted whether they ever produced a Milan Cathedral, still they have given rise to many imposing edifices and why not, therefore, to the halls and corridors of science?

And then, of course, all of these plans unite in assuming that the public investment in science must be made to "pay." Now the author is far from taking the view of certain of his scientific colleagues that any association of commercial value with the products of research is inevitably accompanied by a degradation of ideals. The ultimate object of investigation lies in the attainment of complete control and understanding of our environment and only in so far as our environment is subject to control does it become of value to us. The whole difference between the value of our world to-day and that of the world inhabited by neolithic man is, as I have sought to show in a previous article, the product of the labors of the investigator. But these labors, however inchoate and devoid of the inspiration of a broad predetermined policy, have nevertheless in the past been for the greater part the result of an enlightened and penetrating curiosity and have not as

a rule been dictated by a sense of immediate or personal advantage. They have therefore resulted in the attacking of broad problems, for the nonce unprofitable but in their fruition how deeply fraught with significance to humanity! If the kind intentions of our political friends are executed, however, all this will now be changed, the old academic notion of the remoteness of the investigator from the every-day exigencies of life will be swept away, the unpractical investigation of the laws of atomic affinity will be replaced by an intensive study of cheese-making and the inspiring contemplation of the mysterious structure of the crystal will be replaced by a study of improved methods of hardening steel.

I am far from attempting to impugn the value or the ultimate as well as proximate importance of these studies of immediate practical concern. The Infinite lies hidden in every grain of sand and no object whatever is devoid of dignity as an object of research. Pasteur was led to his epoch-making investigations which have ameliorated so much of human pain and suffering by a study of the problems encountered in the manufacture of wine and of silk. Faraday's genius for research found the path to a new world through his attempts to provide manufacturers of optical instruments with a new and more satisfactory type of glass. But the doubt which assails me is this: Supposing our political friends had by happy chance engaged a potential Faraday or Pasteur to investigate the chemistry of cheese or the hardening of steel and suppose in the course of these utilitarian investigations he too were to tap a vein of knowledge leading deep into the heart of the mysteries of our environment, would he be permitted so unprofitable a divergence from the main object for which he had been hired? However sympathetically inclined his immediate overseer might feel, I think that it might be difficult to convey to the politicians to whom he in turn would be answerable the ultimate significance of such abstract and generalized investigations, and when in turn the matter came to be referred to voters, *i. e.*, taxpayers, I fear it would go hard with our new Faraday or Pasteur.

The wind bloweth where it listeth and the spirit of man can not be confined within premeditated bounds. This human institution, the institution of investigation, must like other human institutions be of natural and spontaneous growth or it will inevitably decay. Just as a church can not be established by statute, nor a system of law be perfected in the brief deliberations of a committee, so scientific investigation must develop of itself, by the expression of its own internal vigor, into an autonomous and self-supporting institution, integrally welded into our daily lives and the living expression of a need and a function of society.

Such, indeed, in slow and painful stages has been the past devel-

opment of science and such, in an accelerated measure, must be its development in the future. There is, indeed, a legitimate sphere for governmental enterprise in that gap between pure science and practical industry which has hitherto been so imperfectly bridged. But the activity of governments in this field can not stimulate the broader activities of the investigator and there is, on the contrary, ground for serious apprehension that the activities of governments in this direction may actually result in depriving the broader and ultimately more significant investigations of the means for their prosecution. The government institutes for research having been founded and munificently endowed, why should further grants and endowments be furnished for investigations which are not carried out under government control? The danger is that cheese-making and steel-making and the like being adequately provided with expert scientific advice the politician may decide that all is now well with the investigator and turn with relief to the more familiar problems of "practical politics."

In order to combat this tendency and to stimulate the spontaneous development of investigation in a measure commensurate with the accelerated velocity of modern social evolution, it is a vital necessity that investigators the world over should at this time take thought and counsel among themselves as to the new ways and means to be adopted, the secular changes in our procedure which will bring our institution of investigation more closely into harmony with the increasing complexity of modern development. Just as, from time to time in the world's history, when some crisis has brought into prominence the misfit between existing institutions and actual needs, the churches have changed and adapted their organization and the existing body of laws and legal procedure have been subjected to reform, so in this day of crisis our institution of investigation must be subject to a like scrutiny and the origin of misfit between existing need and existing procedure sought and if possible removed.

In past centuries the investigator has been largely content to rely for the satisfaction of his personal needs and those of his profession upon the largesse of patrons. So far this procedure has yielded results the vast import of which it would be impossible to exaggerate, and is unquestionably destined still, perhaps for many generations, to provide the main support of this service of mankind, but as the exclusive means of subsidizing investigation it is outworn and ill-adapted to the needs of our present time. To-day we see that increasing patronage, so far from constituting fresh opportunities for science, actually constitutes a grave danger to the welfare of the broader and more fundamentally important types of investigation. The channels are to be made deep for the ultimate trickles, but the fountain-head from which the waters of knowledge proceed is to be neglected, possibly in even greater meas-

ure than in the past, and we may well apprehend that in course of time it may become clogged to the serious impairment of its outflow. The remedy lies in our hands and individually or collectively the decision must be taken now. There is only one solution of our problem and that is to cast off our swaddling bands, cut ourselves loose from patronage, and take into our own hands the destinies of our own institution. While enlightened private patronage will still in a measure contribute towards the achievements of investigation in the future, in ever-increasing degree we must cease to be dependent upon others and look to the product of our own efforts to afford us the material foundation of fresh enterprises. I have elsewhere endeavored[3] to form some imperfect estimate of the monetary equivalent of the colossal value to which the accumulated investigations of mankind have given rise. Where values are so enormous, comprising almost the entire value of existence, such estimates are necessarily only fragmentarily valid. One fact is abundantly demonstrated, however, and that is that by far the greater part of the summated value of the manufacturing industries of our day owes its existence to and depends for its continuance upon the labors of the scientific investigator. Of the vast annual income which is realized by these manufactures and which arises out of their patents a barely discernible fraction ever finds its way back to furnish the means of providing fresh discoveries and fertilizing the field upon which we must rely for the production of fresh growths of industrial enterprise.

If the scientific investigators produce this vast wealth they can also in some measure control its disposal and by observing the guiding principle that in a steadily increasing degree investigation must be made self-supporting, they will undoubtedly in time be enabled to deflect some proportion of this wealth, and a very small proportion indeed would be sufficient, to the services of their institution.

In isolated and strikingly successful instances this principle has already been practically applied. The Solvay Institute in Brussels owes its existence to the wealth proceeding from the discoveries of Solvay. The Institute of Experimental Therapy in Frankfort to which medicine already owes practical results of stupendous significance is supported by the proceeds accruing from Ehrlich's patents and the Research Corporation in New York, deriving its income from the Cottrell patents, is the first instance of a more fundamental and far-reaching endeavor to place the institution of investigation upon a self-supporting basis. It is through repeated independent applications of this principle that the extensions and proliferations of research in future generations are to derive their material bases.

The objection will unquestionably be urged by many scientific pur-

[3] "The Cash Value of Scientific Research," THE SCIENTIFIC MONTHLY, 1 (1915), p. 140.

ists that this procedure would involve the "taint" of commercialism, that once the investigator enters into the market-place his ideals will be contaminated and the purity of his aims sullied. My reply to this is that a fundamental instinct of mankind can not be suppressed so easily. Investigation will proceed even if individual investigators fall by the wayside, and the distinguished instances of successful enterprise of this type to which I have drawn attention are living proofs that the investigators to whom they owe their origin were not so lacking in determination and enthusiasm as to relinquish their life-work merely because personal advantage tempted or the chaffering of the market disturbed them.

Churchmen in all ages have been known to sacrifice personal advantage to impersonal ideals, statesmen have occasionally placed patriotism before profit. Are investigators then so inferior to other men, of so delicate a moral and mental fiber that they will be ready to sacrifice their ideals at the altar of Mammon directly the opportunity presents itself? Or is it, that never having submitted to the trial they are needlessly distrustful of their own moral stamina? I doubt not that the objector would, if questioned, be confident of his own ability to hold fast his ideals, it would be the weaker brother for whom he would be solicitous. Well, let the weaker brethren go, for we can readily spare them, and they too may have their utility in the "debatable land" between science and industry to which I have alluded as a future sphere of governmental or commercial enterprise.

Should the few but noteworthy precedents which have already been set develop, as I am confident they will, into an avowed policy of the majority of scientific men, then a momentous thing will have happened, for science will have capital of its own to dispose of without fear or favor, without deference to the caprice of the patron or the objectives of a donor or the utilities of the moment. When this hour arrives the campaign of the conquest of nature will have entered upon a new phase, and, equipped at last to conquer, a definite strategy of investigation will have become an imperative necessity.

Investigation has hitherto proceeded haphazard, a compromise between the availability of funds and the talents and inclination of the investigator. These latter must always remain a determining factor, but the availability of the paltry means which are usually needful will, it is to be hoped, cease to determine with iron and senseless rigidity the evolution of civilization. At the present time it is comparatively easy to obtain money to endow astronomy, because the subject is in itself inspiring and has never lacked great popularizers and expositors and also perhaps in some measure because a telescope or an observatory is a visible monument to the donor. It is easy to obtain money for objects of real or fancied utility, for the investigation of certain aspects

of medicine or agriculture. But it is difficult to obtain money for the investigation of recondite phenomena in physics or chemistry or for such subjects, for example, as the psychology of insects. Yet if perchance the strategist of investigation were to survey the whole field of scientific knowledge as one might survey a map he would inevitably find that all subjects of investigation are closely interwoven and mutually interdependent. Slowness of advance in one direction cripples advance in another, lack of knowledge in some at first sight unrelated field prohibits the fruition of research elsewhere.

Then, again, apparent value is not in the least identical with the real or ultimate value of investigation. To the man in the street it may appear that the study of fertilizers or of soils, of minerals or of dyes affords at the present time the fields of prime importance. Without in the least detracting from the proximate and ultimate value of such researches, the biochemist, looking a few decades farther ahead, can see in the study of the phenomena of fermentation, of enzyme action, the germ of a future discovery, the artificial photosynthesis of carbohydrates, which will accomplish nothing less than an industrial revolution and sweep aside at one stroke the economic problems of immemorial centuries. Yet with such a possibility lying dormant in the subject, where do we find an elaborately equipped institution for the scientific investigation of enzymes, where leading investigators in the field are congregated and all the resources of modern physics, chemistry and biochemistry backed by the necessary equipment are brought to bear upon this field, fraught with such vital significance to man? If there exists indeed such an institute then I am ignorant of its whereabouts and of the names of the members constituting its staff. The field is not one which has appealed to patrons, the word fermentation reveals to them only the manufacture of beer, which is not the most inspiring of our industries. But the strategist of investigation would place his finger upon this spot in the terrain of scientific conquest and order up reinforcements to support the thinly scattered and ill-equipped forces which at present represent the sum total of human endeavor to enter into possession of this new world which lies before us.

Another subject which will doubtless greatly interest the future Parliament of Science will be that of the geographical distribution of investigation. Here, too, our absolute dependence upon patronage has unfavorably influenced the development of our institution. At present an enormous proportion of organized investigation is being conducted in the vicinity of the large centers of population in Europe and North America. That is partly because of the natural tendency of investigators to congregate in the neighborhood of the patron who endows their labors, and partly owing to the fact that in the absence of any Parliament of Science or analogous deliberative body to discuss such

broad questions of policy, active investigators have arisen to notice in those localities where opportunities are most abundant, new opportunities have been created for them and thus, if this centripetal process is to continue unmodified by some centrifugal policy of distribution, the facilities for research will tend to become in ever-increasing degree confined to a comparatively small number of centers of population.

It is, of course, having regard only to the effects and achievements of investigation, totally immaterial where it may be conducted, but from other points of view the present centripetal tendency of investigation is a serious handicap to the accelerated development of this function of society which is imperatively demanded by the rapidly increasing complexity of our social and material environment. In the first place the congregation of investigators in a single center leads, through constant personal interchange of views, to a certain uniformity of thought which, not infrequently, becomes indistinguishable from prejudice. The scientist who has travelled can not fail to have observed that his colleagues in Berlin, for example, all share a certain number of views regarding the field in which they labor; his colleagues in London will have a somewhat different group of opinions in the foreground of their thoughts, while those in New York will esteem yet a third group of phenomena or hypotheses as of prime immediate importance. This is inevitable, because no investigator, no matter how virile and creative his intellect, can form an opinion from personal, unprejudiced experience on every phase of his chosen subject and he therefore in such matters provisionally absorbs any plausible opinion which lies nearest to hand. His acceptance of such opinions is provisional and subject to revision in the light of fact, it is true, but prior to or failing such revision it must play its proportionate part in determining his mode of investigation in other fields. Obviously a centrifugal distribution of investigation would reduce this tendency towards gelation of hypotheses to a minimum and produce among investigators as a whole that catholicity of outlook and variety of attack which is the condition of success in the interpretation of the myriad manifestations of the complexity of our environment.

But the present centripetal tendency is fraught with yet more serious consequences, for centralization of investigation implies centralization of the opportunities for investigation. At the present date in New York, London, Paris or Berlin the young man who has capability for original investigation has every opportunity of acquiring facilities for his work and for gaining inspiration from the example of investigations proceeding to a successful issue in his own vicinity and under his own observation. He sees in actual operation the methods of work adopted by masters of his subject, and example and opportunity alike combine to make the path easy to his chosen career. But what shall

we say of the opportunities of the young man in Siberia, China, Australasia, South America or Africa? We can not doubt, in some instances we have living proof, that the populations of these countries, granted equality of opportunity, would produce their proportionate quota of talented investigators. In certain localities in these countries every necessary institution exists for providing the essential preliminary training of the investigator, but, training in the fundamentals of his subject secured, where is he now to turn for the living example of the great investigator or for the opportunities of a laboratory partly or wholly devoted to research? The bare possibility of creating fresh fields of knowledge in his chosen territory will probably never even occur to him, since he has never seen or been stimulated to imagine investigation conducted on a broad and practical scale. Thus he turns his energies to other fields and perchance may dissipate on trifles talents which would have been of priceless value to civilization. As a means, then, of tapping new sources of talent for investigation, a centrifugal disposal of investigators and the opportunities for investigation has now become a paramount necessity.

But long ere we can accomplish a fraction of these desirable reforms and developments of our institution a new spirit must arise among investigators themselves. For centuries they have held themselves aloof from the world and centered their regard too exclusively upon their chosen special fields. Few indeed are the investigators of the present day who devote any proportion of their time to reflection upon the ultimate import of their profession, fewer still are conscious of a uniting purpose binding them to the investigators of all lands and times, of the historical continuity of their labors, or of the vital significance of their function in society. The communal spirit which arises from the awareness of common aims and the certitude of irreplaceable usefulness which is the driving force of any and every human institution is as yet, in our institution of investigation, but inadequately aroused. If we are to take our rightful place in the scheme of things and acquit ourselves as becomes our responsibility we can not too soon take these fundamental aspects of our profession seriously into consideration.

And above all let no investigator be ashamed of his profession and let none regard his labors cheaply, for the investigator is the pathfinder and the pioneer of new civilizations; he is more than that, he is the interpreter of the Infinite.

THE DESIRE FOR FOOD IN MAN

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IN these days there is hardly a more commonly accepted principle of human conduct than the tendency to supplant inherited instincts by experience based upon organized knowledge; nor will the teachings of unorganized knowledge prove an acceptable substitute. Unaided mother-love has brought up most of the babies reared to adult stature since the dawn of creation, yet it must confess that modern methods in medicine have bettered its instructions. No longer is it possible for the singer, the engineer, the nurse, the teacher, to make headway professionally without scientific training; and now the cook, the policeman, the saleswoman and the charity worker are beginning to follow suit.

Moreover, in regard to inherited instincts, it has to be admitted that they are sometimes altogether lacking upon most important occasions, or even fundamentally wrong. It is well known that though many animals, thrown into the water for the first time, can save their lives by swimming, the inexperienced human is usually unable to do so. The instinct for scratching an irritated skin is almost ineradicable, yet ordinarily mischievous and often dangerous. The universal liking for so powerful a poison as alcohol, so easily developed by all races of men, has sometimes been cited to disprove any possible theory of organic evolution. Such instances as these may easily be multiplied.

How does this apply to that absolutely universal, most important, and least considered (from the scientific standpoint) of all human performances, the every-day business of eating?

It is perhaps a self-evident proposition, that the human body is, physiologically speaking, a machine, *i. e.*, a complicated system of more or less perfectly coordinated mechanisms, for which foods serve the double purpose of supplying structural material and also fuel which keeps the engines running. It is a deduction which few would care to deny, that any machine will run better and last longer if built of proper materials suitably repaired, and fed with the proper kind of fuel, in amounts suited to the kind of work it has to do. Yet the universal criterion used by the builder, repairer and stoker of this machine is the desire to eat, dignified by some such name as "the normal healthy appetite," "natural instinct for food." And meantime, the tendency of physicians to use "regulation of the diet" rather than medicine, as

a means of combating a long and diversified list of human ills, seems to be constantly and most disturbingly on the increase.

It is to be observed that there is no immunity from any of these ills for the multitude who (explicitly or tacitly) maintain that eating should be entirely an esthetic performance, guided solely by refined and restrained sense gratification and adapted to encourage social intercourse; a performance, then, which can have as little concern with calories and protein, as has the music-lover's enjoyment of a beautifully taken high G, with a consideration of the wave-lengths of the vibrations which produced it. This attitude toward scientific nutrition has, needless to say, as little efficacy in warding off the physical ills resulting from dietetic errors, as has the behavior of the traditional ostrich toward the danger by which it is confronted.

Let us undertake an analysis of the motives involved in the desire for food, as they commonly operate among the various classes of people of our own day and country.

1. Hunger. Beginning with the more fundamental physiological motives, we find that recent investigations[1] seem to demonstrate conclusively a fact which most of us will be inclined to concede at once, or at least after a little reflection, viz., that hunger and appetite are distinctly different motives. Hunger is to be defined as an unpleasant sensation, referred by most people to the pit of the stomach or closely adjacent regions, not caused by the sight or thought of food, but by a certain type of contractions of the stomach muscles which begin as soon as the stomach has been emptied, in normal individuals, and which continue until food is taken. The degree of hunger sensation or pang to which (presumably) these muscular contractions give rise, varies in different individuals, and also, of course, in the same individual at different times. Both the muscular performance and the sensation occur intermittently at first, or in periods of varying intensity, but at length these periods become continuous if no food is taken. In prolonged starvation or undernutrition, however, it seems that the hunger *sensation* (though not the contractions) gradually becomes weakened. Hunger pangs and contractions are almost instantly stopped by the entrance of food or palatable substances into the stomach, or even by fused taste and smell sensations unaccompanied by the swallowing of food. A few spoonfuls of hot soup, though they may contribute little or no nourishment to the body, go far toward alleviating hunger pangs for the moment; even a drink of water sometimes helps; and this would be true even though the liquid were not swallowed, as was proved in case of Mr. V———, Professor Carlson's

[1] Cannon and Washburne, "An Explanation of Hunger," *American Journal of Physiology*, Vol. XXIX., p. 441. Carlson, "Contributions to Physiology of the Stomach," *American Journal of Physiology*, Vols. XXXI.–XXXIX. incl., also "Control of Hunger in Health and Disease," University of Chicago Press.

man with occluded esophagus, who had to be fed with stomach tube. Such facts perhaps indicate to us the biological necessity for the co-operation of appetite with hunger.

2. Appetite is sometimes regarded as a fundamental inherited reaction, and sometimes as being wholly the product of education, *i. e.*, of the individual's experiences with foods. In contradistinction to hunger, appetite is a pleasant sensation, and is invariably associated with the taste, smell, sight or memory of palatable food. It is dependent upon, or coincident with, changes not in the muscular walls, but in the lining membrane of the mouth and stomach. The familiar "watering of the mouth" or psychic secretion of the saliva, connected with the appearance and eating of food which is enjoyed, is a good illustration of these appetite phenomena; and exactly the same thing is happening at the same moment in the stomach, though the individual is not, of course, subjectively aware of this fact.

Here, then, are two great motives having altogether different physiological basis and action (*i. e.*, concerned with different tissues of the body), which ordinarily act together in bringing about and maintaining the desire to eat, until the amount of food taken shall have become adequate for sustenance.

The hunger motive, it seems, is extraordinarily independent of environmental and educative influences, except for certain habitual inhibitions. It can by certain means be caused to disappear instantly, but can not readily and immediately be caused to appear or increase. The strength of its contractions and pangs is, however, influenced by physical vigor and rate of metabolic activity. Moderate muscular work or exposure to cool air augments metabolism and at the same time increases hunger. The young animal, who is metabolizing (*e. g.*, burning food as body fuel) more rapidly and therefore uses more food in proportion to its size than does the older one, also feels more keenly the hunger pang. Again, one may be much more hungry coming home at midnight after the theater (say five hours after the conclusion of the evening meal) than he is before breakfast the next morning (say twelve hours after the conclusion of the last meal); presumably because, in the latter case, metabolic activity is not yet in full swing for the day, and so the hunger contractions can not attain their maximum. And yet, pleasurable appetite sensations connected with the anticipation and appearance of a good breakfast, may lead to the taking of a hearty meal, even though the individual on arising was not aware of any special hunger pain or discomfort.

Not all food materials, however, are valuable to the body in proportion to the appeal which they make to the appetite. For example: the flavor substances in foods which stimulate the olfactory and gustatory nerves and thus give rise to appetite, are not ordinarily the sub-

stances upon which the body depends for its fuel, nor for the great bulk of its building materials. These latter materials—proteins, fats or oils, and carbohydrates (*i. e.*, sugars and starches), when chemically pure, have little or no taste or smell. (Sugars and various mineral salts are of course exceptions to this statement.) But so long as flavor bodies accompany nutritive substances, as is the case in most of the animal and vegetable tissues which man has appropriated for his food, the facts just stated are without much practical significance. When these tissues have undergone manipulation which divorces flavor bodies from nutritive substances, the case is quite different. For instance, in the use of boiled meat, appetite leads us to prefer the broth, which contains most of the flavor bodies (except those which may have escaped into the air with the steam), but which has practically no nutritive value, unless quite greasy; and to reject the tasteless meat, which contains 96 per cent. of the protein; very likely we also skim the soup to remove most of the fat, which is a highly concentrated form of fuel.

The preference for thin and crisp rather than greasy bacon is another illustration of the same thing. In a recent experiment it was found that of the 129 calories which represented the fuel value of a very thin 20 gram (three fourths ounce) slice, only 9 calories remained when the slice was sent to the table; 120 calories being represented by the fat which "fried out" into the pan. In this case a considerable amount of flavor body also goes into the fat, yet most persons would not consider eating it unless it has been skilfully blended with large quantities of other foods; whereas the scrap of skeleton tissue which has lost 93 per cent. of its food value is a dainty morsel.

Many more illustrations might be given to show the great and often inordinate changes in food value of our dietaries, due to some special, sometimes even erratic demand for what the individual has been led to consider a satisfactory flavor or an agreeable texture. These demands are apt to be particularly conspicuous and variable with individuals who are sedentary workers of the middle and upper classes, who live mostly in stagnant indoor air, whose muscular tone is usually low, with relatively feeble hunger contractions. For their appetite sensations, through the development of keen discrimination made possible by the wide choice of foods now offered, even to those of very moderate means, may be exceedingly acute, though their actual food requirement is relatively low.

Let us enumerate several instances of the lack of correspondence between popular demand and actual food value. The sauce made from dried fruits is usually much higher in fuel and even in protein than are the fresh fruits, but the latter are commonly preferred for their more delicate flavor; whether they have any further advantages over the dried fruits (possibly in the presence of the still mysterious

vitamines, or substances of kindred importance, destroyed by heat and drying?) is another matter. Similarly, dried beans and peas as ordinarily cooked will have from two to three times the food value of young green ones. In a general way the same thing is true of most vegetable foods and of many meats. In the case of meats, texture is considered to be of equal importance with flavor, or sometimes of greater importance—as when tenderloin is preferred to the higher-flavored round steak. Yet the tougher cuts of meat are quite as nutritious as the higher-priced ones; and, it may be remarked in passing, can be cooked tender with the development of good flavor and without losing their nutritive value. Price is a rough index of demand; oysters at 50 cents a quart, which is about $2.25 for one thousand calories, or 56 cents for one ounce of protein, are very likely to be preferred to boneless salt codfish at 10 cents a pound, which is 20 cents per thousand calories or 2½ cents for one ounce of protein. Or grapefruit (at 10 cents for the pound size), costing 60 cents per thousand calories, are often selected rather than apples (at 30 cents a peck), which yield a thousand calories for 12 cents. There may be no reason whatever for reversing the choice in either instance, but the justification sometimes urged by the extravagant housewife, that she must have "the best" in order properly to nourish her family, is likely to be without foundation; unless a question of sanitation or digestibility may be involved, as is occasionally the case.

Besides the fact that not all food materials are valuable to the body in proportion to the appeal which they make to the appetite, we must consider the great and often irrational variations to which this faculty is subject. No other bodily sensibility, perhaps, is so easily influenced by habits and customs and conventions, by personal idiosyncrasy and prejudice, by connotating circumstances, by suggestion of every sort, by the emotional complexion of the momentary mood; none, as a rule, so highly susceptible of education. Racial, sectional, religious, social, family, individual experiences—they all have a vote in determining my ideas of what I should have to eat. So, too, does the historical era, the geographical area, in which I live. The skilfulness of my cook may have the largest "say" of all; if she does not prepare vegetables so that they are appetizing, I shall probably eat more meat, bread or fruit, though none of these is an interchangeable substitute for any other. Convenience, the cost of living, and food legislation are sometimes large factors; city life does not conduce to hearty luncheons nor even breakfasts; rich country cream on my oatmeal adds 90 calories to my breakfast over the 18-per-cent-fat-by-order-of-the health-department cream I usually get at my city boarding-house. Varying physiological conditions may act irrationally, as on the hot summer day when I take ice-cream (very likely a more concentrated food than meat) solely for its cooling effect; or when in the midst of the afternoon's

shopping I buy tea and cakes in order to get a chance to sit down for half an hour.

It is evident that many of these factors mentioned above have no conceivable relation to my bodily requirement for food, which is determined chiefly by my age and stature, the amount of muscular work I do, my general nervous and muscular tone, my exposure to cold. Digestibility of food materials and conditions which favor good digestion are essential. Yet it appears that the importance of the enjoyment of food to secure favorable psychic influences upon digestion has been considerably overestimated, since men forcing themselves for experimental purposes to live upon a diet so monotonous as to be repugnant in the extreme, digest it in normal fashion; and similar results usually obtain with forced feeding of animals.

Any condition of food materials causing them to resist digestion will reduce their availability, and in proportion to the delicacy, sensitiveness or robustness of the individual digestive mechanism. The nutritive value of bran biscuits, or of rich pastry, may be zero for some persons, though both protein and fuel values of these two articles are very high when they are fairly well digested and assimilated.

An important factor in determining the nutritive value of the dietary is due to a tendency frequently observed toward large use of "manufactured" or commercially manipulated food materials, and to elaborate blending of these materials by the cook into rich and sweet desserts and other "made dishes," which, though high in fuel value, may very likely be lacking in some of the essential body constituents. Modern processes of food manufacture frequently result in the preparation of highly concentrated food materials—sugars, starches, fats and oils, various dried preparations—whose functions, when they are taken into the human organism, alone or in artificial combinations, are specialized and limited, and whose effects upon the instincts of hunger and appetite may easily be out of all proportion to their useful functions; *e. g.*, starch is isolated from the potato, from maize, from a dozen other sources; fat is isolated from milk as butter, from pork as lard, from the olive as oil. Sugar, a carbohydrate taken from sugar cane, beet or maple, is consumed in enormous and ever-increasing quantities; a recent estimate by a federal authority places its daily consumption at one fourth of a pound per capita, for the well-to-do classes, which would cover 450 calories, or almost 20 per cent. of the total food requirement of the adult sedentary worker, and a larger proportion of the child's requirement. The obvious reason for its popularity is not that it is a concentrated form of body fuel, but that it has a pleasing effect upon the palate (very similar, it happens, to that of saccharin, which has no food value whatever); therefore it is mixed with a large number of other foods. I add "a teaspoonful or two" of

sugar and two or three tablespoonfuls of cream to my saucer of sliced peaches—to be more exact, let us say from three fourths to one ounce of sugar and two ounces of cream to five ounces of peach slices—and consider that I am eating peaches flavored with sugar and cream. It would present the facts much more exactly, from the quantitative point of view, if I should say that I am eating sugar and cream flavored with peaches. For the sugar as fuel is worth 113 calories an ounce, and the cream 108 to 144 calories (according with butter-fat content of 18 per cent. and 25 per cent., respectively; rich country cream runs higher), the peaches are worth 59 calories, or about 20 per cent. of the fuel value of the whole combination.

In cooking fruits, particularly the sour or tart flavored ones, this enormous increase of food value by sugar added for the sake of improving flavor is intensified. The cherry pie which serves six, requires for filling, let us say, five sixths of a cupful of sugar to a cupful of cherries; *i. e.*, seven and a half to eight and a half ounces of cherries worth about 170 to 190 calories, with six and two thirds ounces of sugar, worth 756 calories. The crust of this pie presents another example of combination of concentrates. One half-pint cup of flour (which will be anywhere between one fourth and one third of a pound) is combined with lard or other fat (one twelfth to one half of a pound, according to recipe used) and a small amount of water (two to four tablespoonfuls), then baked until it loses an amount of moisture equal to from 20 per cent. to 35 per cent. of its total weight. This gives the entire crust a fuel value of 700 to 2,200 calories. If we use only a moderately rich crust, and add to the filling an ounce of flour (100 calories' worth) and one of butter (218 calories' worth), we shall have a value of 430 calories for each serving of 3 ounces weight (one sixth of the entire pie). About 30 of these calories are due to the cherries, the other 400 result from the added concentrates (35 per cent. from the fat, 31 per cent. from the sugar). Had the cherries been served as fresh fruit without sugar, a liberal serving of whole cherries would be three and one half ounces, worth some 74 calories; pitted, from three to five ounces (69 to 115 calories) makes a good showing, and most persons would add half an ounce of sugar (57 calories), or some would like twice that amount. As sauce, four ounces would make a good serving; that weight represents four and one half ounces of pitted fresh fruit (103 calories' worth), which would cook down almost to three ounces and would require the addition of at least three fourths ounce of sugar (85 calories), for cooking fruit "brings out the sour taste," and adds to the demand for sweetening. The value of a four ounce serving of the sweetened sauce is then at least 196 calories.

Not many of us would care to consume two ounces of sugar (about seven lumps, or four to six leveled tablespoonfuls) for breakfast with-

out the aid of flavoring materials; yet an ounce on half a grapefruit, half an ounce on breakfast cereal, and one third ounce (one lump) in coffee, are very moderate estimates of the amount eaten by the average person. This addition of 226 calories to the breakfast would easily be doubled by persons with a sweet tooth, and the consumption of a small tablespoonful of marmalade or syrup would mean another hundred calories or more, most (or all) of which are due to sugar.

It is true that sugar is a valuable fuel food, but it is far from being able to supply all, or even a large proportion, of the food requirement. When eaten as it occurs in nature—in fruits, many vegetables, in sugar beet and cane and maple sap—it is taken in comparatively dilute form, and the plant tissue in which it occurs helps to supply small but not altogether unimportant amounts of other food substances which should accompany it, but which are cast aside as impurities in the processes of manufacture. When the sugar is taken in the "pure" or concentrated form—as, for example, in the unhygienic performance of which two school-girls with a half-pound box of candy between them are capable—it has a well-known cloying effect, so that it replaces to an undue extent other needed food principles; or if not, then it contributes to over-eating, that evil so highly prevalent (when a sound digestion permits) in the well-to-do sedentary classes. For the extra sugar adds unnecessary fuel, without being able entirely to replace protein or at all to replace mineral salts as body building material, and without being able to do the work of vitamines, organic acids or bases, and other necessary regulatory substances.

In other words, our fashions in cooking and eating are often too intensive in respect to certain preferred concentrates. No wonder the cry is raised by faddists (and by others) concerning the dangers of "denaturized foods." These statements are not, however, to be taken as an argument against the use of prepared sugars, starches and fats; but as a protest against allowing the dishes made from them to replace wholly such foods as fresh fruits and vegetables. These latter are lower in fuel value, but contain needed mineral salts, organic acids, "vitamines," etc., which are very likely lacking in the rich pudding, flaky pastry, or sweet sauce or confection.

The one factor which ordinarily predominates over others in satisfying the eye and the judgment as to the amount of food required, which brings on the sense of satiety, which prevents the early recurrence of hunger, is, naturally enough, bulk. Yet it is not bulk, but weight and appropriate chemical composition, which determine nutritive value. The result is that when bulk is especially high or low in relation to weight, or when either is due largely to substances edible but not nutritious, the uncritical consumer is likely to vary his allowance widely, without being aware of the fact. To take an illustration

from breakfast cereals: In an ordinary two or three course meal, most persons would perhaps agree that an ounce and a half of any dry, granular, ready-to-serve breakfast food (two or three generous tablespoonfuls) would constitute a reasonable portion; whereas in the case of a dry flaked cereal, the same weight would go far towards filling a pint measure; could hardly be served in the bowl which would be suitable for most cereals, without refilling; and would probably be rejected by most persons as being an unduly large portion; indeed, half that weight would be a more acceptable serving to most. The discrepancy in food value between two such servings of these foods is, then, more than 100 per cent.

Again: In the case of cooked breakfast foods, we have a similar contrast with the more concentrated cereal served in its dry granular form; although the serving of mush or porridge may weigh from three to five ounces or more, most of that weight is due to water taken up in the cooking, and the amount of dry cereal represented in a serving is perhaps from one half to three quarters of an ounce.

The appraisal of food values on page 566 for two apparently similar breakfast menus illustrates again the influence of accessories (cream, butter, sugar) upon food values, as they help to double both protein and fuel figures for the second breakfast. It is to be noted that hot muffins usually "take more butter" than does toast, and toast more than does cold bread. Here is also illustrated the contrast in food value between a watery (cooked) and a concentrated cereal; a contrast still further enhanced by the fact that these cooked cereals are usually eaten with a smaller amount of cream than are the dry ones. Again, the psychology of serving is interesting; many persons who "could not possibly eat two eggs for breakfast" when the boundary line between eggs is plainly to be discerned, will nevertheless find a one-egg serving of scrambled egg rather too small; so that many housewives prefer to allow an extra egg or two in making the family dish. Serving a chicken presents similar problems; two two-and-one-half-pound chickens carved at the table may "go further" than one five-pound chicken, not because they furnish more meat (very probably they actually furnish less) but because they furnish a greater number of cuts which can be served.

But since this "natural instinct" or "normal appetite for food" has brought the human species thus far and safely through the long records of history and biology, why should any one now contemplate its abandonment, even for a moment?

To answer this question, let us consider these four propositions:

1. The preservation and improvement of the human species as a whole, and of its individuals, has come to depend upon very different factors from those which governed its welfare when the laws of this

BREAKFAST I

	Weight in Oz.	Protein, Grams	Calories[2]
Cantaloupe (with rind, 16.4 oz.) without rind	6.6	1.4	93
Corn or wheat porridge (uncooked, ½ oz.), about	4.44	1.54	51
Cream, 25 per cent. fat	1.43	1.08	100
Sugar	0.50		57
	6.37	2.62	208
Toast, 3 slices (thin; bread untoasted, 1.48 oz.)	1.10	3.90	109
Butter, 1 pat	0.50	0.14	109
	1.6	4.04	218
Egg, poached, 1	1.57	5.90	65
Butter, 1 teaspoonful, about	0.25	0.07	54
	1.82	5.97	119
Coffee, ⅜ pint	6.35		
Cream, 25 per cent. fat, 1½ tablespoonfuls, about	1.00	0.76	70
Sugar, 3 level teaspoonfuls or 2 small lumps	0.50		56
	7.85	0.76	126
Total breakfast	24.24	14.79	764

BREAKFAST II

Sliced peaches	5.00	0.98	57
Cream, 25 per cent. fat	2.00	1.52	140
Sugar	1.00		113
	8.00	2.50	310
Wheat grits of some kind, ready-to-serve	1.50	4.81	156
Cream, 25 per cent. fat	2.50	1.90	175
Sugar	0.50		57
	4.5	6.71	388
Muffins, 2	3.0	8.25	275
Butter, 1½ pats	0.75	0.21	163
	3.75	8.46	438
Scrambled egg:			
Eggs, 1½ per serving	2.36	8.85	98
Milk, 1½ tablespoonfuls, about	1.25	1.16	24
Butter, 1 teaspoonful	0.25	0.07	54
(Cooked weight 3.56 oz.)	3.86	10.08	176
Coffee as above	7.85	0.76	126
Total breakfast	27.96	28.51	1,438

2 These calorie values have been obtained by the use of Atwater or Sherman factors, chosen to allow for average losses of food not digested. These factors are, 4 calories per gram for proteins and carbohydrates, 9 for fats.

inherited instinct were evolved. The "survival of the fittest" involves the extermination of what we may charitably denominate "the others." But the nobler elements of modern human sentiment demand the protection, not to say the cherishing, of the unfit; who thus survive and hand on their legacy of ill adjustment to another generation. Furthermore, in these days of the supremacy of certain qualities of gray matter, such as shrewdness and "business faculty," and of human tools, the industrial (non-human) machines, it is far from being the case that the man who is muscularly fittest has the best immediate chance of survival, even if we leave all the works of human altruism out of consideration. By various means is the inevitable punishment for physical degeneration greatly delayed; and so vital a matter as a lack of adjustment of fuel or building material to body requirement, in spite of its ultimately more or less serious consequences, may go long with little remark. For instance, where in the "state of nature" does one find an over-fat animal? The struggle is too keen, to permit such to survive. Yet the over-fat human is by no means an uncommon phenomenon.

2. Furthermore, the fact that serious and rather common errors in nutrition are considered by physicians as important contributing causes to diseases which usually develop in middle life, and which result in long morbidity of insidious development lacking in the spectacular element produced by sudden mortality—this fact of the long delay of punishment tends to obscure the nature of the error. It is true, however, that having accomplished something toward the conquest of bubonic plague and cholera, typhoid and even tuberculosis, we are beginning to ask ourselves why it is that certain diseases are so constantly on the increase. For answer (in part, at least), it is more and more frequently mentioned to us, that overfeeding, that is, feeding too much protein, or too much fuel, or both, is often a predisposing factor of some importance in such cases as these: kidney and gall-bladder infections and inflammations, certain kinds of disturbance of the circulatory system (*e. g.*, arteriosclerosis, high blood-pressure diseases), various infections of skin or mucous membranes (from a common cold to the most serious eczema cases), and even possibly cancer.[3]

3. The voluntary muscles, which in the activities of the human animal in a "state of nature," use probably 75 per cent. of the fuel

[3] The author does not wish to be understood as making the claim that these diseases—*e. g.*, gall-stones, Bright's disease, diabetes, etc.—always, or often, have overeating as a sole or chief cause, even though it is so frequently mentioned as one of the causes. It must be remembered, too, that most points regarding the relation of diets to disease are still more or less in the controversial stage. Moreover, it must not be forgotten that the dangers of under-nutrition (especially in persons under 30 years of age) are equally serious with those of overeating.

which the body requires, have in this last century had their activities suppressed and curtailed as never before; this is true not only in sedentary (business or professional) but also in large sections of the industrial classes. We should expect, then, that the traditions, customs, and "instincts" of the frontiersman, the hard-working peasant, the soldier, who use from 4,000 to 6,000 calories' worth a day when they can get it, and need it all, may not necessarily prove a wise guide in the matter of food consumption, for their descendants, the bookkeeper, the broker, the skilled artisan, the factory hand, whose requirements are 2,500 to 3,000 calories a day. Hunger may be diminished by lessening muscular work, but appetite is not necessarily so; indeed, it seems that nerve-poisoning and heightened irritability resulting from overstrain and unhygienic indoor living may sometimes unduly heighten (instead of interfering with) the appetite for food; this is also the case with the other appetites, sensibilities and cravings of a "nervous" person, in many instances.

4. The changed condition of food materials due to the excessive utilization of high concentrates and to the use of artificial flavorings, has already been discussed; as has also the inadequacy of an inherited instinct satisfied by bulk in the stomach, for limiting the amounts of these concentrates which should be eaten.

The discrepancies, then, which are so frequently to be observed, between food requirement and food consumption, may be explained as due in part to present lack of adjustment to recent and enormous changes in environment and human activities and in the nature of foods. It seems quite possible that adaptation of diet to the activities of the organism, and other important hygienic measures, may come about, not simply through the slowly accomplished downfall of degenerate classes and nations, which history has so often shown us—for neither the rich fruits of shrewd business capacity nor the activities of the altruistic can ultimately shelter physical deterioration—but through the further discovery of the principles of scientific management of the human organism, and through the apprehension of these by the enlightened classes and the consequent practise of them by the world's population. Should we, indeed, expect the scientific intelligence to accomplish so much less striking results in the study of the structure and conduct of our own machine, than in that of the simpler non-living machines? Is it reasonable to assume that the laws of scientific feeding which man has already begun to apply with some success to other animals, will fail to produce results with the human species itself?

THE PSYCHOLOGY OF WAR

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MY intention is not to discuss the causes, economic or political, of the present incomprehensible conflict in which some of the leading nations of the world are each unconsciously committing suicide. Neither do I intend to attempt a justification or condemnation of any of the parties now in arms. I seize this opportunity of trying to convince the public that the forces that move humanity are so deep and so subtle that we are constantly substituting surface and relatively unimportant causes for the deeper and real causes.

Spencer long ago showed that every form of human conduct has its roots and earliest manifestations in primitive man. Even human sympathy, the only force on which the anti-war spirit can safely build, and the only one that has wrought any inner change for real humanism, is not absent in the lowest savages.

However, it is not enough to say that war is founded on human instincts as old as the race. Many then jump to the conclusion that man is hopelessly doomed to war until the Judgment Day. Of course we are, if we properly understand the Judgment Day. Does not every organism struggle to live and to live at any cost? But you say: "Do people really war to live?" Not in this day. This impulse is joined with other impulses. There is an instinct of pugnacity manifested in nearly all people. You explain this in yourself as "righteous indignation." It is all right for us to fight, but never right for our enemy to fight.

Again, can we not trace everywhere the human impulse to excitement, to adventure, to insatiable achievement, to deeds of daring? There is also the instinct of emulation closely allied to the instinct of imitation. Perhaps the early forms of emulation are akin to the powerful forces of envy and jealousy, known to animals and common to all mankind. Race hatred is surely an instinct.

Nearly all individuals and all races have been dominated by the instinct of revenge. Let even a hereditary defective kill some of your friends, and then stand by and watch the course of vengeance. It is still not unlike savage vengeance. The life of the criminal is demanded on the respectable objective grounds of the good of society, but uppermost in the heart of the offended is vengeance. The savages always avenge any wrong done any individual of their group by indiscriminate punishment of the whole tribe. This is war. Later, this

punishment was, as we see in the Bible, limited to the family of the offender. Furthermore, vengeance is one of the most permanent of all feelings. It may last for years, and even be instilled in the coming generation. But the most remarkable thing is the extent to which vengeance passes as justice. Half of our cries for justice on our enemy are nothing but vengeance.

Finally, one more instinct should be mentioned—fear. Fear is the stamp of the coward. But the coward that fears to-day may fight to-morrow, because continued fear is the worse of the two evils. When fear is once turned loose it is cruel beyond measure. When Schiller was analyzing the human heart to find the most ungovernable, the most "don't care" emotion of man, he pointed out terror as that emotion. Terror is fear gone mad.

The manifestation of these instincts of economic possession, to have and to hold, of pugnacity, of self-elation, of achievement, of imitation, of envy, of jealousy, of race hatred, of fear, of vengeance, cooperating to the same end, through a few million years, have developed habits and customs that carry these forces beyond their aims and continue them in operation even when the grounds for operation have disappeared. When joined with intelligence, the instincts develop the most powerful forces of human society—sentiments of superiority, of egotism, of love and hate, of patriotism, of economic dominance or morals, of honor. Each age or peoples of the same age, who have developed different sentiments, pronounce damnation on all others. Here, and not in the intellect, is the foundation for all the divergent and dogmatic claims about justice, right, human welfare, etc. Such interpretations and claims are chiefly based consciously or unconsciously upon what the individual or nation feels to be of most vital personal interest.

If any one could make a careful diagnosis of all the forces operating in producing the war spirit in the United States to-day, he would find every one of these forces at work on the people of our country, even down to the contradictory absurdity of imitating Germany. We are only dimly conscious of the most powerful forces that move society.

While war is by all odds the dominant rule with savages and primitive peoples, there are those who rarely if ever engage in war. It is also true that there are other instincts, impulses and sentiments that have always been developing in opposition to these forces that make for war. To claim that might, and might alone, makes right is certainly a one-sided view. It is equally wrong to claim that might has nothing to do with making things right. No small part of our international laws have been directly or indirectly dictated by the most powerful. Truth, honor, justice, beneficence and love of mankind have been developed largely through human intelligence, but they are nevertheless founded on fundamental instincts, and most generally their interpre-

tation and application are mixed with all the instincts connected with war.

I in no wise minimize the place of intelligence in the mighty march of what we call civilization, but it has always followed the lines mapped out by instinct, impulse and human sentiments. Why do we not all abandon war? Every form of human intelligence is against it. Why do we not abandon our ancient and barbarous system of treating criminals? Psychological, biological and sociological sciences are against it. Simply because the accumulated forces of opposing instincts and sentiments are not yet strong enough to overcome the massive accumulation on the other side.

Such a well-known authority as McDougall, speaking of Central Borneo, says in his "Social Psychology":

> . . . villages and tribes live in a state of chronic warfare: all are kept in constant fear of attack, whole villages are often exterminated. This perpetual warfare seems to be almost wholly and directly due to the uncomplicated operation of the instinct of pugnacity. If one asks of an intelligent chief why he keeps up this senseless practise of going on the warpath, the best reason he can give is that unless he does so, his neighbors will not respect him and his people. How shall we begin to understand the prevalence of such a state of affairs, if we regard man as a rational creature guided only by intelligent self-interest, and if we neglect to take account of his instincts? And it is not among barbarous or savage peoples only that the instinct of pugnacity works in this way. The history of Christendom is largely the history of devastating wars from which few individuals or societies have reaped any immediate benefit, and in the causation of which the instinct of pugnacity has played a leading part. In our own age the same instinct makes of Europe an armed camp occupied by twelve million soldiers, the support of whom is a heavy burden on all the peoples; and we see how, more instantly than ever before, a whole nation may be moved by the combative instinct—a slight to the flag, or an insulting remark in some foreign newspaper, sends a wave of angry emotion sweeping across the country, and two nations are ready to rush into a war that can not fail to be disastrous to both of them. . . . The Germanic tribes were perhaps more pugnacious and possessed of the military virtues in a higher degree than any other people that has existed before or since. They were the most terrible enemies, as Julius Cæsar found; they could never be subdued because they fought, not merely to gain any specific ends, but because they loved fighting.

All history affords evidence of this smouldering war-volcano. Hundreds of individuals said to me on the outbreak of hostilities in Europe: "Is it not awful, foolish, unchristian, and barbarous? Surely we could never do such an irrational thing." Since that time most of these same people have caught the war fever and believe we should take a part in the war. This is simply common psychology. At one time cool intelligence speaks, at another strong feelings. The outbreak of our own Civil War will illustrate this law. The lions of the north and south were fully aroused. Brother was ready to butcher brother in the name of justice and right. Ministers outraged every form of human

intelligence in an effort to justify antagonistic principles and to reconcile religion to war.

Out of primitive savage warfare modern militarism has developed. Until recently political power was inseparable from military power. In early society all adult males were warriors. The army and the community were one. Men had just two ways of getting a living—out of the soil and out of other men. In primitive society, hunting and warring were joined in one occupation. The war chiefs also became the political leaders, and even to-day the two are only partially separated. In many cases, the ruler, knowing the favor and prestige of the military position, makes sure that he is either the head of the army or that he indirectly controls the army. This is true in our own country.

Later, the development of intelligence and fear compelled tribes and nations to some kind of union. Failure in the war usually ended in suspicion and hate among the defeated allies, and victory meant a quarrel over the spoils. When the present struggle ends, you will realize that this law still holds good. But victory also meant some kind of a standing army to guard the possessions. So we have had the constant union of tribes, peoples and nations against others, with the universal development of a standing army.

Everywhere the development of a standing army for defense has sooner or later passed over into offensive operations. Thirty years ago Herbert Spencer pointed out this law with many concrete cases. He says in his "Sociology":

> Always a structure assumed for defensive action, available also for offensive action, tends to initiate it. As in Athens the military and naval organization which was developed in coping with a foreign enemy, thereafter began to exercise itself aggressively; as in France the triumphant army of the Republic, formed to resist invasion forthwith became an invader; so is it habitually—so is it now with ourselves. In China, India, Polynesia, Africa, the East Indian Archipelago, reasons, never wanting to the aggressor are given for widening our empire; without force if it may be, and with force if needful.

The causes for this universal tendency are many. A well-organized fighting force always calls for readjustment in other nations, and this in turn creates fear, suspicion, and a demand for enlarging our forces. There is no letting go. Soon suspicion deepens into alliances, these into readiness to strike before it is too late. In the meantime every power of science is being employed to perfect the system of organization. In the eyes of those employed, this military organization becomes the nation. Among the many articles in our magazines, from men of military and naval prominence, how many can you find that do not declare war a necessary evil and tell us that we must not expect it to end or even diminish? How insistent are their demands for increase of army and navy? This is what we know in psychology as the power of apperception. A man who lives constantly in one atmosphere can

only interpret everything through that influence. This is not peculiar to the warrior. It is the same with the minister, with the millionaire who justifies his existence as such, with the Russian who believes his government superior to all others. We blame no one for it. At the present hour the harsh and brutal accusations men are bringing against their brothers would largely cease if only we fully comprehended this principle and its power over human opinions. Is it probable that any officer can escape the conscious and unconscious influences of possible honor, promotion and victory that might result from war? You may minimize it as much as you please; but, if our present type of officers is immune to these and other appeals which would cause them to lead us into war, we have suddenly developed a type of man not mentioned in history.

In how far may envy, jealousy, desire for personal gain, race hatred, vengeance, etc., creep into our interpretations of moral law, moral truth, justice, honor, the weak brother, etc.? In how far do they dictate what peace with honor is? Of course, we are always asking such questions about other people's idea of good and right, honor and justice; but rarely ever apply the same examination to our own. In all such cases, it is alarming to observe how absolutely certain we are that our interpretations are the correct ones. Do we not know that neither prejudice, hate, envy, vengeance nor personal interest of any kind enters into our judgments? I insist that the attitude neither of the millionaire nor the socialist, of the saloon-keeper nor the minister, of the warriors nor the lovers of peace, of the English nor of the Germans, must be interpreted as insincere or hypocritical.

What is defensive warfare? Well, suppose we have a big army and navy. Suppose Japan allows some of our citizens to be murdered over the sea. It is defensive warfare to avenge the wrong? Is it simply active justice that duty compels us to perform, in which neither vengeance, jealousy, nor race hatred takes any part? Or, suppose the people of India begin to groan under the burden of foreign rule, would it not be easy to decide that in the interest of humanity, justice, right and of the weak brother, we should wage a war in defense of their liberty? In such events would not every one of the war impulses and instincts demand a part in our interpretation and application of justice, moral right, benevolence, humanity, honor, weak brother and defensive warfare? The so-called man of practical business affairs may laugh at our psychology and refuse to recognize the power of these things; but that only proves the alarming danger to which we subject ourselves in entering upon the war policy.

To intimate, as Mr. Garrison and other war writers do, that we shall have self-control, that we shall not follow the rule of passing from defensive to offensive preparedness, is to betray our common conceit

and ignorance of human nature. We do not see that present sentiments will gradually give way to others. We do not see how one step calls for another, and yet another. Do we not all boast as to how we should act if we were millionaires? How shall we best find out what we should do under such circumstances? The best way conceivable is to select a thousand or two who have become millionaires and see what the majority have done. We shall, in spite of our honest convictions conceived under present conditions, in all probability act like the people whom we condemn.

It would be difficult to find a more clear-cut contradiction between intelligence and feeling than is presented in our consideration of preparedness. We try to blind ourselves to the fact that such considerations are prompted by all the instincts and feelings that make for war everywhere. The most unreasonable and unlikely fears are everywhere presented as the basis of action. Parallels and analogies of the most absurd kind are evidenced everywhere, Everything is done to array sentiment against intelligence. We cry out: "Look at England and France! See their fate for not being prepared." Are we to infer from this that our military preparedness is to go beyond what theirs was? Prominent public speakers and magazines compare the intended preparedness to our necessity of police and to "guarding against burglars." Suppose other nations so adroitly called us burglars. We should immediately want to defend our honor. Even *The Outlook* goes beyond this and compares it to preparation against fire and to the subjugation of the citizen by the state. One writer compares it to the obedience which a switch produces in children. Are we to be the state with all other nations our obedient subjects? Under the influence of such wild analogies the whole nation may become war-mad.

The fundamental psychological facts are: We have been surprised, and our mental peace has been taken from us by the revelations of a preparedness so far surpassing ours that we do not see ourselves so much of a world power as we had imagined. In spite of our boast of moral strength, we repudiate our Christianity and admit that we must rely more on physical force than on moral power for our "place in the sun." It is an interesting panorama of moral contradictions. We can not see that such evidences of practical righteousness as the repeal of the Panama Canal Tolls Exemption Act will do more to keep us out of war than fifty battleships.

Our pride has been touched, our hate aroused, our jealousy kindled, our imagination set going. We want to be able to strike, not when we are invaded (who would wait so long as that?), but when our trade is interfered with, when any more citizens are killed on the high seas, and to liberate those whom we think outraged by other heartless people. We want our army and navy to speak in the councils of the world.

Six months ago we talked only of defending our coast. Now we are talking of defending the weak brother and protecting our honor. There is not a man in public life who could not go out and shoot some one down on the grounds of an offended honor. All of the warring powers are sincere in believing that they are fighting for justice, honor and self-preservation.

A congressman said to me the other day: "How are we going to defend ourselves when Germany has guns that shoot eighteen miles?" I said: "Suppose we make guns that shoot twenty miles, and she makes guns that shoot thirty miles. Suppose we build ten battleships and she builds as many, are we any better off? Does it not simply mean greater certainty of war and greater destruction when it comes? How is any one nation to know that she is the best prepared? If she did know that, how is she to know what combinations will be made against her? Must we not always expect the weaker ones to combine against the stronger ones?" Alas, the politicians will see none of these things. They are trusting to chance to modify events in the future. They look on at the military conditions in Germany with bitter criticism, but they can never be made to see that the gradual growth of militarism in this country can produce similar strong sentiments for war. They do not see that the very democracy on which they rely to save us from the destiny of other nations owes its perpetuation largely to its freedom from militarism.

They will not listen to such sound psychological advice as President Butler, of Columbia University, was reported as giving in the *New York Times* for October 18, 1914. He says:

> **It is not each nation's desire for national expression which makes peace impossible; it is the fact that thus far in the world's history such desire has been bound up with militarism.**
>
> **The nation whose frontier bristles with bayonets and with forts is like the individual with a magazine pistol in his pocket. Both make for murder. Both in their hearts really mean murder.**
>
> **The world will be better when the nations invite the judgment of their neighbors and are influenced by it.**

If war was such a psychological necessity in the evolution of man, why is it not so still? When the whole male population constituted the army, the weak, feeble and cowardly were the ones weeded out. Modern militarism has exactly reversed this process. Our wars leave the race to be replenished from the most unfit. In past times one race or tribe either annihilated or made slaves of the weaker race. Races are no longer exterminated or enslaved. Modern methods of warfare make war absolutely impoverishing to all parties, even to the victors. Suppose the Japs should want to take from us the Hawaiian Islands. How many lives and how much money are they worth? Are they worth a single battleship with a thousand soldiers that may go down

and the heartaches of a thousand mothers? If that is the way we are to value life so late as the twentieth century, we may well hope for Huxley's friendly comet that will wipe this world into non-existence.

The developing instincts and sentiment that were once too weak to oppose war have been steadily gaining ground. This makes conditions quite different from what we find in the early history of men. Nothing has been so much needed to allay hatred and to bring about a proper understanding of conditions as a psychological explanation of conduct in war. Right is a very slippery word, especially when it is applied to the criticism of others or to those whom we dislike. But you say: "Have not agreements made some things wrong and others right?" Yes, the first criminal laws of Pennsylvania made twelve crimes punishable by death, and at the same time England applied the death penalty to over two hundred offenses. How long will the agreement for the state to murder criminals driven by circumstances and heredity to their destiny continue to be right?

I am inclined to think that all our agreements about having a humane war are mistakes; because they delude us into believing that we are civilized and are civilizing war. Such persons should see the humor in the title of an article in *The Forum*—"Thou Shalt Not Kill" in War.

Both history and the study of human nature warrants us in giving as a general law that all the so-called civilized nations will act very similarly in war under similar circumstances. This is not saying that no nation has any moral superiority; but I do mean to say that our moral superiority is by no means what we constantly assume it to be. It would be too painful to cite all the historic proofs that come to mind. How common it is in daily life for us to say: "If I were in such and such a one's place, I should not do so and so." What we really mean is that with our present ideas, judgments and feelings we should do so and so. We do not figure on the changes that would come over us in these changed conditions. So long as the intellect has the right-of-way, the lately acquired forms of conduct and character of individuals and of nations remain comparatively stable. But when the older forms of instinct, custom and passions are aroused these are easily set aside. Only those who have studied history from the standpoint of human feelings, as Le Bon has suggested, can understand what it means to invade an enemy's country with bitter hatred in your heart and with all the brutal instincts that war arouses. Neither do we realize what it means to try to judge where hatred and enmity are involved. There never was a time when men so much needed to apply some psychological analysis to their own opinions, beliefs, condemnations and praise.

Finally, if war has been backed by a network of instincts and sen-

timents, if preparedness only hastens war and more of it, what is the psychological remedy?

1. I have emphasized the fact that from the beginning sympathy, tender emotions, humanitarian feelings, kindness, benevolence, love, truth and justice which is not all vengeance, have been accumulating a force in opposition to the other instincts. Selfish intellect could never establish insane asylums, hospitals, red cross societies, homes for the aged, care for cripples and defectives, and abolish barbarous systems of punishing criminals. It is this altruistic fund of feeling, augmented by every intellectual effort of man, on which we shall build our forts to storm the forts of militarism. It is slow, but the outlook is not discouraging. I admit that the militarists are correct when they say that physical force has always spoken louder than moral force; but I do not admit that it must or will always be true. Why can we not see that it is just that kind of thinking that has kept physical force dominant?

2. How shall this be brought about? The surest avenue that psychology knows is through the education of the people. Several years ago we undertook to educate the people in the dangerous effects of alcohol. The liquor interests were all unconcerned. But now, look at the result. Whenever we speak against war we are called idealists and dreamers. I am not deluded by any idealism. I have presented the cold facts that the war impulses are too strong for intelligence. There is no mathematical axiom truer than this: So long as the majority of the people or of those in authority think we must have war and prepare for it we shall have it. Shall you or shall you not help to keep it going?

But let us not be absurd and attempt to teach peace and militarism in our schools at the same time. The boy that wears a uniform and at the same time receives formal instruction in peace and good will to all mankind will always have enough war impulses surging in him to laugh at such contradictions.

3. Again, we shall move on with our already large and highly perfected organizations for peace even if military writers continue to say these efforts have amounted to nothing. Militarism must be overthrown from without; the masses of the common people must do it; and it must come first from democratic countries. The psychologist does not look for it soon, nor as the result of any convention of those dominated by the war spirit.

Let all the nations abandon their system of trying to rob each other by tariffs. Let the government take all our munition plants and manufacture munitions only for our own use. There is not one man in a thousand who, if he speaks from his heart and not from some council acts, will not say that the only proper neutrality at all times would be to sell munitions to none of the warring nations. Let us cease to as-

sume that nations are going to attack us. The fortunes of war are always staggeringly uncertain. Our military men can give us no more assurance of victory twenty years hence with five times our preparation than they could with just the preparation we now have. Let us cease to think we must fight—as the savage did—that our neighbors may respect us. Let the religionist stop quibbling and outraging his intelligence to find a sanction for war in the teachings of Christ. The Christian should either frankly admit the fallibility of the teachings of Christ or confess that he can not pursue war and at the same time be a follower of Christ.

I may not live to see these things come to pass. But militarism must die or all intelligent thinking men will become discouraged, if not disgusted, with all our boasting about civilization and Christianity. Sympathy, kindness, self-control, peaceable sacrifice must triumph over man's lower instinctive nature. Those who ring the bell should never be discouraged because they can not march in the procession. Be sure it will follow.

RATING THE SEVERAL SOVEREIGN NATIONS ON A BASIS EQUITABLE FOR THE ALLOTMENT OF REPRESENTATIVES TO A WORLD PARLIAMENT

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THE ultimate evolution of a World Federation to preserve the international peace and to coordinate certain human activities involving international intercourse is—howsoever long its coming may be delayed—highly probable. But before the several nations of the world actually succeed in organizing such a government they must agree upon an *equitable formula* as a basis of representation to the legislative body. In the House of Representatives of the United States Texas has 16 representatives, Pennsylvania 32, and Arizona 1. This is based upon population—the *formula* agreed upon by the makers of the Constitution. The people of the whole United States accept this apportionment as a matter of course; but, if an *equitable formula* had not been agreed upon, it is quite certain that quarreling over the one problem of apportionment would be a cause of discord sufficient to vitiate the purpose of the whole Union. All will agree that the general judgment of any possible body of alloters, howsoever honest and well informed they might be, could not satisfy the constituent members of a federation with their allotments nearly so well as such members could be satisfied with their respective allotments resulting from a *mathematical formula* worked out in accordance with collected data.

In the United States the *population formula* works well, because in any given state the average American is about as intelligent, as prosperous and as patriotic as in any other state. But among the nations of the world there exists, as well as a great range in their participation in the world's work, a wide variability in the proportion-mixture of their elements of national greatness. In a constituent convention each nation would, therefore, strive to make its greatest quantitative asset a most important factor in apportioning representatives to the Parliament of Man. Most certainly this difference of opinion concerning the *proper formula* of representation will prove to be the first great stumbling block to progress in any constituent assembly actually intent upon working out a plan for the political organization of the world. Small nations will argue that all sovereign nations should be equally represented; yet equitability, not necessarily equality, is the only just basis of representation in governing bodies generally. When

TABLE I

ALLOTMENT TO WORLD PARLIAMENT: NATIONAL ASSETS EQUITABLY WEIGHTED

		Sovereign Nation (Including Their Colonial Allotments as per Rule *B*)	Total Per Cent. Rating	Rating on the Basis of 500 Representatives	Major Fractions	Final Allotment of Representatives to the World Parliament
Basis:—	1.	British Empire	.18491	92.459	—	92
Rule A.	2.	United States of America	.13877	69.388	—	69
1. Land area potential to supporting civilization—all of the world's land, excepting the frozen polar and the arid desert wastes.....5%	3.	Germany	.10202	51.013	—	51
	4.	Russia	.09772	48.863	1	49
	5.	France	.08224	41.123	—	41
	6.	Netherlands	.04486	22.443	—	22
2. Land area actually supporting civilization—all of the world's populated land over which law and order prevail.....10%	7.	Austria-Hungary	.04423	21.127	—	21
	8.	China	.03986	19.931	1	20
	9.	Italy	.03536	17.688	1	18
	10.	Japan	.03019	15.097	—	15
	11.	Belgium	.02869	14.347	—	14
3. Total population.....10%	12.	Brazil	.02505	12.525	—	12
	13.	Spain	.01803	9.015	—	9
4. Population partaking of the world's work—all persons reported as "literate" in census returns, and in other more or less authoritative estimates.....25%	14.	Argentine Republic	.01702	8.510	—	8
	15.	Switzerland	.01175	5.886	1	6
	16.	Sweden	.01121	5.608	—	5
	17.	Mexico	.01097	5.486	—	5
	18.	Turkey	.00929	4.647	1	5
5. Foreign commerce...50%	19.	Denmark	.00623	3.120	—	3
	20	Portugal	.00623	3.119	—	3
Rule B.	21.	Chili	.00558	2.792	1	3
1. Home territory of sovereign nations—full rate.	22.	Norway	.00521	2.601	—	2
	23.	Rumania	.00486	2.434	—	2
2. Autonomous colonies and semi-sovereign countries—half rate.	24.	Cuba	.00485	2.427	—	2
	25.	Colombia	.00403	2.018	—	2
	26.	Persia	.00357	1.788	1	2
3. Non-autonomous colonies—quarter rate.	27.	Peru	.00263	1.307	—	1
	28.	Bulgaria	.00249	1.250	—	1
4. Each sovereign nation to have at least one representative.	29.	Bolivia	.00237	1.189	—	1
	30.	Venezuela	.00210	1.051	—	1
	31.	Uruguay	.00195	.976	—	1
5. Colonial and semi-sovereign country evaluations accredited to the mother or sponsor country.	32.	Siam	.00197	.937	—	1
	33.	Greece	.00175	.880	—	1
	34.	Serbia	.00165	.828	—	1
	35.	Equador	.00094	.474	—	1
	36.	Guatemala	.00070	.354	—	1
Rule C.	37.	Paraguay	.00058	.294	—	1
1. Total number of representatives: 500.	38.	Salvador	.00057	.287	—	1
	39.	Panama	.00050	.251	—	1
	40.	Haiti	.00049	.246	—	1
	41.	Santo Domingo	.00044	.221	—	1
	42.	Costa Rica	.00038	.193	—	1
	43.	Honduras	.00030	.155	—	1
	44.	Nicaragua	.00025	.128	—	1
	45.	Montenegro	.00013	.067	—	1
						500

Note.—This schedule does not include the results of the recent "*Balkan Wars*"—nor of course of the present "*Great War.*"

The area of the entire world is included under the above 45 sovereignties. The semi-sovereign nations were assessed at half rate and their ratings accredited to their respective sponsor nations.

These tables show only the summaries. The full details of the calculations are omitted for lack of space.

TABLE II

ALLOTMENT TO WORLD PARLIAMENT: BASIS OF TABLE I MODIFIED SO AS TO CAST NATIONS INTO POWER GROUPS

Rule.—Add the allotments (Table I.) of the first and the second nations; divide by 2. If the quotient is not at least twice as great as the allotment of nation No. 3, add the allotments of Nos. 1, 2, and 3; divide by 3 and compare as before with the allotment for the next succeeding nation (this time No. 4), and so on until the comparison shows a drop of at least 50 per cent. between the quotient and the allotment for the next succeeding nation. Assign to each nation whose original allotment entered the dividend an allotment equal to the quotient. Discard the remainder, then proceed anew with the succeeding nations.

	Sovereign Nation	Final Allotment of Table I	Calculations	Final Power Group Allotment	Compared with Table I
1.	British Empire	92	302 ÷ 5 = 60 + 5 *First-Rate Powers.*	60	Loss, 32
2.	United States of America	69		60	Loss, 9
3.	Germany	51		60	Gain, 9
4.	Russia	49		60	Gain, 11
5.	France	41		60	Gain, 19
6.	Netherlands	22	122 ÷ 7 = 17 + 7 *Second-Rate Powers.*	17	Loss, 5
7.	Austria-Hungary	21		17	Loss, 4
8.	China	20		17	Loss, 3
9.	Italy	18		17	Loss, 1
10.	Japan	15		17	Gain, 2
11.	Belgium	14		17	Gain, 3
12.	Brazil	12		17	Gain, 5
13.	Spain	9	38 ÷ 6 = 6 + 6 *Third-Rate Powers.*	6	Loss, 3
14.	Argentine Republic	8		6	Loss, 2
15.	Switzerland	6		6	—— 0
16.	Sweden	5		6	Gain, 1
17.	Mexico	5		6	Gain, 1
18.	Turkey	5		6	Gain, 1
19.	Denmark	3	19 ÷ 8 = 2 + 8 *Fourth-Rate Powers.*	2	Loss, 1
20.	Portugal	3		2	Loss, 1
21.	Chili	3		2	Loss, 1
22.	Norway	2		2	—— 0
23.	Rumania	2		2	—— 0
24.	Cuba	2		2	—— 0
25.	Colombia	2		2	—— 0
26.	Persia	2		2	—— 0
27.	Peru	1	19 ÷ 19 = 1 *19 Fifth-Rate Powers.*	1	—— 0
28.	Bulgaria	1		1	—— 0
29.	Bolivia	1		1	—— 0
30.	Venezuela	1		1	—— 0
31.	Uruguay	1		1	—— 0
32.	Siam	1		1	—— 0
33.	Greece	1		1	—— 0
34.	Serbia	1		1	—— 0
35.	Equador	1		1	—— 0
36.	Guatemala	1		1	—— 0
37.	Paraguay	1		1	—— 0
38.	Salvador	1		1	—— 0
39.	Panama	1		1	—— 0
40.	Haiti	1		1	—— 0
41.	Santo Domingo	1		1	—— 0
42.	Costa Rica	1		1	—— 0
43.	Honduras	1		1	—— 0
44.	Nicaragua	1		1	—— 0
45.	Montenegro	1		1	—— 0
		500		490	

The data for the calculations were taken largely from "The Statesman's Year Book."

the geographical units of a federation are inhabited by persons of nearly equal, howsoever different, average attainments total population has proved to be the simplest and fairest basis of apportionment; but the individual human units of the world's civil units are by no means equal in their participation in the world's work, hence total population would not be a fair basis of apportionment of legislative voice among nations. To a proposal to make it such China would answer "Yes"; Holland, "No." If foreign commerce were proposed, England, Holland and Germany might answer "Yes"; Italy and Austria-Hungary, in company with all of the smaller of the younger nations, would probably say "No." If area were proposed as the measure, Russia and Brazil would answer "Yes"; Switzerland and Belgium, "No." Shall colonies give additional weight to the mother country's allotment? Britain and Holland would answer "Yes"; Sweden, "No."

Granted that in a constituent assembly each nation would evince a genuine willingness to consider all of the elements of national greatness possessed by every other nation, nevertheless the tangle would grow, and the conference would end in confusion and discord, unless an *impersonal and mathematical formula* embodying their notions of justice could be found. Why, then, not weight the principal assets of national greatness in proportion to their bearing upon the world's work? The United States, in particular, can afford to be conciliatory in the attempt to reach an agreement by this road, for its faith in the federal idea, based upon experience, is sincere and clear, and its elements of national greatness, while quantitatively great, are harmoniously balanced, so that almost any just formula would give her about the same percentage of the sum total of the rating of all of the several sovereign nations.

The accompanying tables, one and two, represent an impartial effort to rate the nations of the world in national assets, giving due consideration to those factors which make nations intrinsically great and participatory in the world's work. Table three shows the unfairness of depending upon any one single national asset as a basis for rating nations for equitable representation in a World Parliament.

There should be secured from representative men of every profession of every nation and colony of the world the *formula* which each man individually considers *just* and would be willing to see his *own* country subscribe to. These formulæ should then be worked out in apportionment tables with as great accuracy as the obtainable data will permit. There are now in the United States a number of agencies working actively for the promotion of international peace and world government. Among them are the "Carnegie Endowment for International Peace," the "World Peace Foundation," the "League to Enforce Peace," the "American Peace Society," the "International Peace Forum," the "American Peace and Arbitration League Inc.," the

TABLE III

Other Schemes of Allotment to World Parliament

In each case: (1) Five hundred representatives. (2) Based upon *one only* of the five national assets which contributed to the allotment of Table I. (3) Based upon the asset of the *home territory only* of the sovereign nation, *i. e., not* adding the ratings of colonies and sponsored countries to their respective mother and sponsor countries as in Tables I. and II.

Nation No. and Rank in Table I	Sovereign Nation: Home Territory Only	Basis: Total Land Area Potential to Supporting Civilization		Basis: Total Land Area Actually Supporting Civilization		Basis: Total Population		Basis: Population Partaking of the World's Work		Basis: Foreign Commerce	
		Allotment	Rank	Allotment	Rank	Allotment	Rank	Allotment	Rank	Allotment	Rank
1.	Great Britain and Ireland	3.34	23	7.39	15	23.00	7	45.12	4	96.21	1
2.	United States of America	81.93	2	185.42	1	46.62	3	90.24	1	63.15	3
3.	Germany	5.74	15	12.72	7	32.65	4	56.40	3	69.64	2
4.	Russia	56.12	3	29.60	3	66.51	2	84.60	2	21.43	7
5.	France	5.70	16	12.62	8	19.96	8	33.84	6	46.14	4
6.	Netherlands	.35	41	.77	37	2.99	19	5.64	13	41.97	5
7.	Austria-Hungary	7.19	14	15.90	5	25.21	6	39.48	5	19.08	8
8.	China	42.21	4	12.18	10	152.08	1	11.28	10	5.49	16
9.	Italy	3.05	25	6.75	16	17.52	9	28.20	8	17.94	9
10.	Japan	4.83	19	10.70	12	25.73	5	33.84	7	8.16	13
11.	Belgium	.31	42	.70	39	3.59	15	5.64	14	26.40	6
12.	Brasil	88.67	1	60.95	2	10.88	11	6.77	11	9.73	12
13.	Spain	5.29	18	11.70	11	9.89	12	16.92	9	6.28	15
14.	Argentine Republic	31.28	5	15.24	6	3.54	16	3.39	17	12.58	10
15.	Switzerland	.44	39	.97	34	1.85	25	3.95	16	10.01	11
16.	Sweden	4.76	20	10.54	14	2.78	20	5.67	12	6.99	14
17.	Mexico	21.12	6	21.94	4	6.90	13	4.51	15	4.44	18
18.	Turkey	20.91	7	12.19	9	12.08	10	3.38	18	3.27	21
19.	Denmark	.42	40	.91	35	1.31	30	2.26	19	5.02	17
20.	Portugal	.95	33	2.09	26	2.36	21	2.26	26	2.03	24
21.	Chili	8.06	13	5.49	22	1.68	26	1.13	24	4.06	20
22.	Norway	3.42	22	6.62	17	1.21	31	2.26	21	3.12	22
23.	Rumania	1.40	27	3.09	23	3.48	17	2.26	22	2.97	23
24.	Cuba	1.21	31	2.44	24	1.09	32	.63	29	4.32	19
25.	Colombia	11.98	11	10.67	13	2.20	23	1.13	25	.23	35
26.	Persia	18.73	9	6.10	18	4.82	14	.34	35	1.32	26
27.	Peru	19.17	8	6.09	21	2.28	22	1.13	26	.09	42
28.	Bulgaria	1.04	32	2.32	25	2.17	24	1.69	23	1.05	27
29.	Bolivia	16.68	10	6.10	19	.93	35	.56	30	.59	30
30.	Venezuela	10.85	12	6.10	20	1.36	27	.56	31	.47	32
31.	Uruguay	1.98	26	1.83	27	.56	38	.29	36	1.54	25
32.	Siam	5.37	17	1.83	28	3.17	18	.23	37	.98	28
33.	Greece	.69	35	1.52	29	1.34	29	1.13	27	.82	29
34.	Serbia	.52	36	1.14	32	1.36	28	.79	28	.52	31
35.	Equador	3.20	24	1.22	30	.65	36	.34	33	.43	33
36.	Guatemala	1.33	29	.73	38	1.01	34	.56	32	.13	41
37.	Paraguay	4.72	21	1.07	33	.32	39	.17	40	.16	40
38.	Salvador	.20	44	.18	45	.57	37	.34	34	.23	36
39.	Panama	.86	34	1.21	31	.23	42	.23	38	.18	38
40.	Haiti	.27	43	.43	42	1.03	33	.23	39	.18	39
41.	Santo Domingo	.48	38	.91	36	.31	40	.11	42	.22	37
42.	Costa Rica	.50	37	.43	43	.19	44	.11	43	.24	34
43.	Honduras	1.27	30	.49	40	.25	43	.17	41	.08	43
44.	Nicaragua	1.36	28	.49	41	.21	42	.11	44	.07	44
45.	Montenegro	.10	45	.22	44	.13	45	.11	45	.04	45
		500.00		500.00		500.00		500.00		500.00	

Note.—The home territories of the sovereign nations of the world possess:

35.10% of the world's total area potential to supporting civilization.

52.87% of the world's total area actually supporting civilization.

61.72% of the world's total population.

92.47% of the total population partaking of the world's work.

80.91% of the world's total foreign commerce.

"American Society for the Judicial Settlement of International Disputes," the "New York Peace Society," the "Woman's Peace Party," and the "League for World Peace." Although most of them doubtless have their own programs of work, it is hereby proposed that they consider the desirability and the feasibility of collecting and working out a large number of apportionment formulæ. The value of a volume of 5,000 such tables properly classified and summarized, to the members of the next Hague Conference would be very great. Thus systematic canvassing and careful mathematical tabulation as well as direct educational propaganda would promote world federation.

OUR DUTY TO THE FUTURE

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IN a certain western city a prominent portrait photographer has for many years used the slogan, "Preserve the Present for the Future." While his chief work, naturally, has been the preservation of the likeness of human beings, his advertising contains an appeal to the sentiment of his patrons that might well be the sentiment of all of us toward every worthy product of human endeavor.

There may be found in this slogan the germ of an idea that appears to have been given but slight consideration in our present age of hurry and worry, hustle and bustle, strain and stress. This idea may be expressed broadly as the desirability of making some definite effort to preserve our present-day knowledge, along with the best products of man's hand and brain, in a form that will endure as long as the Pyramids, or even much longer. With our present scientific knowledge and spirit, the glories of this age ought to be recorded and made intelligible to posterity in a manner that could be equalled or surpassed only by posterity. There should be a concerted effort and aim of living civilized men to preserve a representative portion of the present for the future.

There are probably few men in the scientific world who do not think it well worth while, and even necessary, to take an interest in some branch or branches of science outside of their own specialties. One may go even further and say that many scientific men take more or less interest in all sciences. While it may be nothing more than a guess, yet it may be stated as a probability that the majority of the readers of THE SCIENTIFIC MONTHLY belong to this latter class. If this is true, or even half true, it may be assumed that this article is addressed to a considerable number of men who are interested to a greater or less degree in the fascinating science of archeology.

The ephemeral, transient character of most of the present works and products of man is readily noted. What bearing will this fact have upon the future? Any person who is familiar with the work of the many enthusiastic, patient and long-suffering archeologists of the last sixty years will recall the problems and difficulties which have harassed these workers. While many most interesting and noteworthy discoveries have been made, they have cost much money, time and labor, and the best years of many worthy men. Let us ask ourselves if it is right that we, with our costly experiences in attaining what is at best but an imperfect knowledge of ancient civilizations, should be indifferent as to

the records we leave, or the lack of them. Is there not a possibility that the archeologists of the future will find it proportionately as difficult to obtain an accurate knowledge of our present civilization as our present archeologists have found it to learn about the past? It may be worth while to consider what our duty is in this respect to posterity.

In this discussion we may find it convenient to indicate the modern products of man's hand and brain, that have at present a permanent or recorded form, as "works." Those of the past might be referred to collectively as "ancient works." Before we proceed further in our argument, it might be well to examine the modes in which the works of man may be or have been destroyed. And by destruction we mean the state of ruin in which we have found many ancient works, as well as the utter ruin which leaves practically no trace or residue.

Most of the natural forces that appear to have accomplished the ruin of ancient works can be considered as being just as effective now as they have ever been. Possibly we should still consider man as an intentionally destructive agent, present world conditions being so closely analogous to those of the past.

The first natural agent that probably most readily suggests itself is vulcanism, with its accompanying or brother calamity, earthquake. One scarcely needs to enlarge upon the series of disasters of this character that have occurred within historic times. Nearly every year we still find that earthquakes and volcanic eruptions occasion great damage and loss of life somewhere on the earth. If a building is to withstand earthquake, it must be exceptionally well built, and its site and foundation prepared with some care. Or, on the other hand, the buildings have to be, like those in Japan, constructed of materials that may be destroyed by other agents, if not by earthquake. Vulcanism may be terribly destructive in several ways. One is by the burial of cities beneath great quantities of volcanic "ash," sand, lapilli, etc., as at Pompeii; another, by the flow of hot lava over and through the works of man; still another, by the swift discharge of large volumes of hot and poisonous gases, as at St. Pierre. One might almost say that more ancient ruins were caused by earthquake and vulcanism than by any other natural means.

Considering wind, water and fire, one may readily recall the known effects of these natural agents upon ancient works. Violent winds or tornadoes have doubtless visited man's habitations in the past as they have in modern times, and in their effects have been as destructive to certain structures as fire or earthquake. The Deluge of Biblical history seems to have been something more than a mere tale. Even the legendary continent of Atlantis may have existed as a large island or archipelago, finally destroyed by tidal waves and seismic disturbances. Floods and deluges are prominent in the folk-lore of peoples over nearly the whole earth. We moderns have had experiences with floods, tidal waves, and the like, which have shown us the destructive power of

water, and its sudden and unexpected attacks. The past has witnessed many an ancient work ruined or damaged by water, and here also the hand of nature was seen more often than that of man. On the other hand, destruction by fire has doubtless been occasioned much more often by man than by nature. Whether started by accident or by design, fire has ever been a terror to all peoples. While many ancient works were of a character to remain to a large extent unaffected by fire, yet some of the things most desirable for us to have known about were utterly lost, being readily combustible. It is certainly fortunate for us that such a large number of written records were made on stone, clay or metal instead of on so combustible a substance as papyrus. What would we not now give for manuscripts long since destroyed, as those in the famous library at Alexandria, or the Aztec writings burned by fanatical Spaniards? We are able to see, then, how these agents, the primitive elements, air, water and fire, have affected man's works in the past, and what may be expected of them in the future.

Still other natural forces deserve our attention. Among the most prominent of these are the two extremes, glacial and desert conditions. The destructive action of ice and snow is to be seen somewhere almost every season on a relatively small scale. But what of a frigid epoch like that of the Pleistocene when half a continent was covered with immense ice sheets? We only have to be reminded that in those times the destruction of nature's own works was enormous, in order to realize what might have happened to ancient works, and what may yet happen to our own works of to-day. Whether acting as glacier, iceberg or floe, ice must be reckoned with as a possible natural agent in destroying the so-called "imperishable" habitations and monuments of man. And with ice we must put the avalanche, a swifter but less powerful ally. One might also speak here of landslides, an agent of destruction that is not at all unfamiliar in many parts of the world.

The desert areas of the globe afford us some excellent examples of the effect of torrid and arid conditions upon man's works. The deserts are quite frequently areas of violent atmospheric disturbances with almost an entire lack of precipitation and consequent dearth of vegetation. The soil is sand, or alkali, or a mixture of these, and the winds keep the small dry particles in almost constant motion. Rock surfaces are soon cut, etched, and eroded to an astonishing degree by the force of nature's sand-blast. Is it surprising that there are but few inhabitants, and these mostly nomadic, in the desert places? Yet on the sites of several present desert regions there flourished in ancient times civilized peoples whose only relics that remain to us are a few ruins of stone buildings, a few mummies, some specimens of pottery, and a few metallic ornaments. The present Sahara desert was in recent geologic times the home of animals that subsisted upon abundant vegetation. The Desert of Gobi has overtaken and concealed cities

of the ancients, of which little remains but a few ruined walls. The coast of Peru, possibly as rainless a region as may be found, has beneath its sands the remains of a people of unknown antiquity. The remarkable ancient city of Petra is situated in a peculiar many-colored rock-walled valley in the midst of a desert. It was wholly lost to the world for over a thousand years. On our own Atlantic coast, and elsewhere, we can readily follow the sand dunes as they travel inland, burying and destroying forests and villages. The known work of the wind, aided by sand, especially in a rainless, tropical region, suggests a natural agent of destruction—an enemy of man's handicraft that may be expected to certainly overtake and destroy, somewhere, sometime, the objects of art and culture that modern man has so carefully and painfully constructed.

Finally, we might make mention of the part man has taken in accomplishing the destruction of the works of his brother. War, disease, pestilence, the torch, starvation, and like allies of savage man, have wrought great destruction of material things, either directly or indirectly. The effects of fire have been referred to. War, hand in hand with disease and starvation, has leveled and depopulated many a city and country, and most often the victors in war have removed their loot and carried off their slaves, leaving the works of the vanquished people to lie uncared for and in ruins. Sometimes the fortunes were reversed, where a race or tribe of people who had been taken captive eventually carried out a successful rebellion, returned to the sites of their former cities, conquered or drove away any foreign race, and built their cities anew. In the course of time these cities were cast down in ruins once more.

Innumerable questions arise in the tracing of the fortunes of many peoples whom we moderns know only by the ruins and relics we have found. When we inquire into the reasons for the disappearance of a people, or the discontinuance of their civilizations, we can not always be sure that the proper agent or agents have been selected, since in the end the effects of several different agents may be so similar. Who were the Mound Builders, the Cliff Dwellers, the Toltecs, the Mayas, the Pre-Incas, the Cambodians, the mysterious dwellers of Easter Island? What was the origin of each of these peoples? In most cases we do not even know when or why they disappeared, much less their history. Were they exterminated or forced to migrate by natural agents, or by a conquering race? Have their works fallen to decay as a result of nature's behavior, or has nature been assisted by the hand of man? Doubtless, these and all similar questions will be fully and definitely answered sometime. But are we to wait until that time arrives before we are moved to consider the history of these and all such races, and learn one of the most serious lessons such consideration has to teach us?

Our present-day museums contain many wonderful, curious, instructive and interesting objects. The museum is a real factor in education, and the vast amount of labor and money spent on these treasure houses of art, history, science and industry has been in most instances well spent. Further, the value of the exhibits and collections has increased with the passage of time. In fact, it is almost axiomatic that the further we become removed in time from the moment of its fashioning the more valuable an object becomes. In but few instances, however, can we be said to be taking definite action to "preserve the present for the future." We have by great diligence acquired some knowledge of man as he lived before our time, with some of his relics, monuments and works of art. We take great pains to transport and preserve Egyptian obelisks and tombs, Babylonian inscriptions, Aztec gods, and even Libby prisons and presidential birthplaces. What is the future of these? Will the coming generations fail to receive or acquire an interest in these things equal to our own? It would seem probable that there will be men five or ten centuries hence who will have an interest in not only their own national history, but also that of peoples who seem ancient or semi-ancient to us. It would seem that our duty to the future lies in not only preserving our own present-day relics, but also in leaving some adequate and authentic account of our own times with such illustrative material as may be considered necessary or desirable.

It seems almost needless to point out that we ought to be beyond leaving our records and relics to the future in any indefinite or haphazard manner. Yet if we ask ourselves what we have done or are doing to safeguard our historical treasures and works of art, what answer is to be found? Have we taken into account the possibilities? Suppose this country should be visited by some unprecedented and widespread series of disasters, originated by the forces of nature—what would be left? What is there that we now have that could withstand earthquake, vulcanism, tornado, tidal wave, fire, ice or sand dune? Suppose our museums and monuments escape one or several of these destructive agents, are they able to withstand all? What is there that we may really call permanent, that we may set up to defy all the forces of nature until the next geologic era?

Let us see if among the present known materials there may be found one that we may call the ideally resistant material. The rocks of the earth's surface have always appealed to man as the very essence of endurance, changelessness and permanence. In the stone age man learned that some rocks were very hard, dense and durable; that others were soft or brittle; that some rocks could be shaped by using pieces of harder ones, and polished by the powder of others; that some were adapted to the fashioning of weapons and implements, idols, inscriptions, and ornamental designs; that rocks resisted fire and the weather,

and afforded a shelter from heat, cold and storm, and a barrier to enemies. While man has since learned the manufacture and uses of other materials, he still seems to place his greatest faith in stone as a means of combining dignity, utility and permanence. The most famous and nearly the most ancient stone monuments are the Pyramids of Egypt. They have endured so long as to seem almost indestructible. But let the climatic conditions be altered to correspond with central Africa, or even the interior of the Sahara, and the Pyramids would be much less able to resist the forces of nature; their period of duration would be greatly shortened. Earthquake is perhaps the greatest destroyer of structures in stone, yet man has learned how to build, if he will, so as to withstand even violent earthquake shocks, as evidenced by the wonderful mortarless masonry of the Incas, in Peru, a land that certainly can not be said to be free of the peril of earthquake. Reinforced concrete is probably the best modern material that might be used to withstand earthquake shocks. The concrete work at Panama, a region that has seen considerable seismic disturbance, will probably afford us information as to its stability in due time.

It might be remarked in this connection that reinforced concrete seems to suffer but little from the effects of fire, unless the heat be exceptionally intense and prolonged. Many rocks, however, do not pass the ordeal of fire without becoming thereby more readily attacked by weathering agents. Granite, marble, limestone and sandstone, four of the most used building stones, endure heat rather unequally. Both marble and limestone are decomposed by heating, passing into ordinary lime. Digressing for a moment to the use of marble in ancient art, we are frequently struck by the lack of foresight, or of knowledge, of the ancient as well as medieval and some modern sculptors in choosing marble as the final expression of their art. Pure white marble is undoubtedly beautiful; but, supposing some vandal desires to satisfy his appetite for destruction by pulling down marble statues, shattering them by blows, or forever destroying them by fire? Modern artists never cease grieving over the incompleteness of many of the ancient masterpieces, known to us only in a fragmental or damaged condition.

Granite and sandstone may successfully withstand earthquake and fire, but they, as well as less stable rocks, can not be entirely free of the effect of vulcanism. The well-known effect of molten lava upon sandstone, changing it to quartzite, would be the final chapter in the history of an edifice of sandstone, overtaken by a lava flood. And in the case of either granite or sandstone, a lava flood would so fill and surround and alter the structure that it would be as good as lost forever. The earthquake and volcano belts of the earth have been carefully traced and defined, and are found to be practically identical in position. The association of earthquakes with volcanoes is very striking; but are we quite certain that these belts will always remain as they

are? Is there not a possibility of their shifting, very gradually perhaps, but nevertheless with a distinct movement, noticeable every fifth or tenth century? The question is one that can not be definitely solved. The belts will doubtless move together, but can we say that any given portion of the earth's crust will be forever free of earthquake or vulcanism?

Man seems to delight in building his cities as near to danger as possible. Witness the manner in which the peoples of the Mediterranean insist on staying by their volcanoes, and rebuilding their shattered cities. Taking an example at home, may not San Francisco run the risk, with other coast cities, of being destroyed once more, or possibly several times, by earthquake? The archeologists of the future may find several buried cities on the present site of San Francisco, if man insists on living at that point as the Pacific coast littoral becomes broader, and the Sierras rise higher to the accompaniment of unnumbered quakings and tremblings.

But even though stone, the favorite building material since prehistoric times, is able to survive or be spared the effects of earthquake, fire, vulcanism and flood, it is still subject to final and complete disintegration through the slow but continued action of the weather. Wind, rain, frost, the gases of the air, and even the humblest living organisms combine to overthrow that which man has erected, and which may have withstood all other destructive agents. In this respect granite is almost as unstable as the other varieties of building stones mentioned. The coarser the grains in a granite rock, the more easily the rock crumbles. It is readily split or fractured by frost, by trees, and even by the heat of the sun. Limestones and marbles are slowly dissolved by the carbon dioxide in rain and in percolating waters. If in contact with soils and vegetation, a similar effect is observed, due to the same cause. Sandstones may resist the effect of frost, rain, and carbon dioxide, but succumb at once to the chiseling effect of sand particles driven by the wind. Running water is often more active than wind, rain or air in disintegrating and pulverizing rocks; while a glacier either moves bodily whatever comes in its path, or rides over it and crushes it to the finest powder. After reviewing thus the effects of the principal destructive agents upon stone, to put our faith in stone as the sole protection to our treasures of the past and present would seem to be open to several objections.

Next to stone, we find man has discovered and placed a value upon certain substances which he has learned to call metals. At the present time we may be said to be living in the age of steel. Iron is our most important metal as it is the most useful and most abundant, or rather, is the cheapest and is most readily obtained in large quantities. Yet iron is the most perishable of all metals. Rust is the chief enemy of

all our iron and steel objects. To avoid rust has been the aim of man ever since he discovered iron and its uses. When quite pure, the rusting of iron is greatly retarded, but it is scarcely possible to indefinitely defend even pure iron against rust. Fire, sea-water, and ice, as well as the weather, could destroy a structure of iron in the course of time, and even in much less time than it would take the same agents to destroy a structure of stone. When properly imbedded in concrete, however, iron or steel not only adds greatly to the strength of the concrete, but is very much less liable to rust, owing to the protective effect of the cement.

If iron is of doubtful permanence, will other metals or alloys serve better? Undoubtedly some of them might, to a certain degree. Bronze is surely very resistant to the weather, as are its components, copper and tin. These, however, could be readily melted in a fire, as could zinc, aluminum and lead. Gold and silver are even more resistant to corrosion and high temperatures, but their cost prevents their extensive use. The same is true of platinum, tungsten, vanadium and still rarer metals. We can scarcely choose a single metal that will serve as an ideally resistant agent or material and at the same time be of practical use.

Clay products often appeal to us as having singular powers of resistance to certain destructive agents, but in all cases such products are found to have some fatal weakness. While quite resistant to the weather, and to a certain degree of heat, yet severe weather conditions or intense heat may destroy them. In most cases the practicable forms of these products are brittle, and for that reason are readily damaged. Ancient inscriptions in clay have been preserved for a very long time, and are of great interest and importance in archeology, but we should remember that the destructive agents directed against them did not include severe weather conditions nor high temperatures.

Possibly the most resistant mineral substances that appeal to modern man are asbestos and its allied minerals, talc, steatite and serpentine. These lend themselves readily to the shaping of numerous articles. Asbestos in particular is very familiar to us in its uses as a fire-proofing material and non-conductor of heat. Softness and brittleness, however, are objectionable properties of most products from these minerals, just as brittleness is a characteristic weakness of kaolinite or clay products.

Glass, while hard and resistant to the weather, is too readily injured by high temperatures, and is too brittle to give us much hope in our search for an ideally resistant material. While glass is of enormous importance in our modern civilization, it seems probable that most of it will remain in its present forms only under quite favorable conditions.

If the substances so far discussed are unsuitable for the purpose of perpetuating or safeguarding our records and relics of ancient and

modern times, the natural query is, "In what way or ways may we preserve the present for the future?" Most of our historical, scientific, religious, social, political and other kinds of documents are composed of flimsy and combustible materials, on which it is easy to almost completely and permanently obliterate or efface the written or printed record. The bulk of our modern paper is less permanent than that made two and three hundred years ago, or even the papyrus of the ancients. Yet we entrust our most precious records to the surface of a substance that can not be expected to endure two thousand years under the most favorable conditions. Photographs might be better preserved in the form of the original glass plate, or a non-combustible film, or best of all, as a half-tone or similar metallic engraving. The photographic print, or the print from an engraving is certainly as perishable as the paper on which it is made. History, art, literature, science, and written knowledge as a whole, may be transmitted to posterity in the form of copies, if necessary, using the proper measures to ensure authenticity as well as safety in preserving and protecting such copies until they are to be recopied or rewritten. But what of the originals of many historic documents, photographs, and the like? Will not these relics be of greater interest and value if they, and not mere copies, are preserved for the future? Copies of certain things, particularly works of art, are not always desirable, nor can these things always be copied to the best advantage. We may admire and cherish beautiful and costly mural paintings and other decorations, but can we be certain that the buildings containing them will escape complete destruction? The beautiful Library of Congress could be hopelessly ruined by a few well-directed bombs from a fleet of hostile airships, if not by the shells from some long range naval gun. Could its art treasures, not to speak of other kinds, be successfully restored? What would happen to the National Museum, and the museums, libraries, and art galleries of our coast cities in case of war and sudden attack? Have we any adequate or efficient means of preserving the products of man's genius and inventive skill? What machines could withstand the destructive agents cited? Do these questions concern us, or do they not?

Several years ago Mr. Percival Lowell wrote as follows:[1]

> One reflection well worth our thought the pyramids suggest: the enduring character of the past beside the ephemeralness of our day. We build for the moment; they built monumentally. True we have printing which they had not. But libraries are not lasting. Fire, accidental or purposive, has destroyed the greater part of the learning of the far past and promises to do so with what we write now; and what escapes the fire mold may claim. Only that idea which is materially most effectively clothed can withstand for long the gnawing disin-

[1] *Popular Science Monthly*, Vol. 80, p. 460 (1912).

tegration of time. The astronomic thought of the pyramid-builders lives on to-day; where will record of ours be, I wonder, five thousand years hence. We may be quoted indeed with ever-increasing inaccuracy of description. . . .

What answer can we make to this? Our nation has endured and prospered for one hundred and forty years. There are reasons for supposing that it will endure for another century, or two or three or ten centuries. But nature will not be idle all this time. She moves slowly, it may be, but nevertheless most surely. Is there not something that we, who are living here and now, can do to add to the good name which we all sincerely wish, as the United States of America, to leave to posterity?

We are greatly concerned in the topic of preparedness, for war or for peace, according to the way in which we recognize our individual duties and interpret our national needs. Is it wholly out of place to suggest that we also prepare for the contest which the objects we have fashioned and which we have held to be worthy must make with Mother Nature? Why should we stop at one thousand or five thousand years as the limit of our responsibility? What of us and our descendants ten—twenty—fifty—one hundred thousand years from now? If man is still man, will he not then have as great an interest in his antiquities as we have in ours? Knowing the conditions with which our present students of archeology have to contend, are we to take no thought of the possible problems of the future? The ancient monarchs who ruled flourishing empires thousands of years before our time have in many cases done us an inestimable service in causing their names and deeds to be inscribed in the most durable form known to their art. Are we to make no use of our superior knowledge in preserving for the future, not only our collections of antiquities, but an adequate record of our own national progress and current thought?

If it may be assumed that there is a modicum of agreement on the proposition of preserving the present for the future, we may naturally begin to inquire, what is to be done, and how shall it be done? The first question raises another of much greater scope, namely, what shall be selected, in case a move is made to preserve definite things for the benefit of future antiquarians? Possibly this question could best be settled by a commission, appointed by and under the direction of the federal government, sufficiently large and representative to bring forth all sorts of views on the problem. The work of such a commission would doubtless include discussions, decisions, and investigations concerning the worth and claims of the thousands of things that would be suggested on every hand. It is true that thousands of corner-stones of public buildings all over the country contain a record of a certain kind. But how adequate would such records be? We have in the corner-stone custom a primitive attempt at leaving some sort of record for the

future, in which we are outdone many times over by the customs of the ancient dwellers of Egypt and Babylon. We may have Halls of Fame, and galleries of statues, but they are necessarily somewhat too exclusive and intangible to satisfy the desires of the archeologists of the future. We might emulate the enterprise shown abroad in preserving phonograph records of living orators, singers, and instrumentalists. But why stop there? Our modes of recording history and noteworthy events seem to be at the height of perfection, and the preservation of photographs, moving-picture films, as well as the voices of our leading national figures is to add to the future an untold wealth of interest in us and what we have done, together with a better understanding. The selection, then, of that which we ought to make an especial effort to preserve would probably be based upon the relation of the objects and records to the history, progress, culture and life of the nation as a whole. That the project should be financed and carried out by the federal government will probably be agreed to by all.

As a secondary function of our hypothetical commission there remains the necessity of determining how we shall go about it to preserve these things, once they have been chosen. Our review of destructive agents, noting what they have done and still may do, as well as the consideration of the amount of resistance to these agents possessed by our present materials, causes us to confront the problem with some degree of anxiety, since no one of the materials known to man will serve for all the requirements of the problem's solution. This phase of the movement would likewise need careful thought and discussion, and it would probably be found that only a combination of materials would satisfy the requirements.

To paraphrase a well-known quotation, we can not predict in what century the "New Zealander will gaze on the ruins of Brooklyn Bridge." Nor can we say at what moment the hand of the invader will be stretched out to destroy or snatch away our treasures. It is true that in time of war, or under threat of ruin by fire, earthquake, glacier or volcano, we could remove a portion of our works of art, our relics of state, and our rarest collections to some safer quarter of the country. But would such a move be final or satisfactory? When the Washington monument and Grant's tomb are but rocky ruins in a watery waste, what will have become of the lesser works of the nation that erected these tributes to the memory of two of their most illustrious men? Let us determine that what we do leave shall be as well preserved as the remains of the trilobites of fifty million years ago, and that our mode of preservation shall contain less of accident and more of thoughtful design. Looking forward, can we see this as a portion of our duty to the future? If we can, let us set about the fulfilment of our duty, as becomes true Americans.

THE FAVORITE NUMBER OF THE ZUÑI

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IN the briefest acquaintance with Zuñi custom and tradition one is struck by the prominence of the numeral four, by its in fact obsessive character. It was on the first day of a recent visit to Zuñi I began to notice it. I had happened on the last of the summer so-called rain dances—the *kokokshi*. In the forelocks of the male figures in the dance were *four* yellow feathers, the bead work on the heel band of their moccasins represented the *four*-armed cross, their dance had to be repeated *four* times, I was told, in *four* plazas of the pueblo. Accompanying the dance or, so to speak, during its interstices, the *koyemshi* fooled about, and those antic figures the Americans call "Mudheads" numbered ten; but in their formal exit from the sacred plaza the *koyemshi* marching two by two divided into two slightly spaced sets, *four* in the first, six in the second. As I learned later, six and ten also play special rôles in Zuñi numeration, but they are, it is fair to say, quite minor rôles. As for eight and twelve, they figure too, but they figure as multiples of four.[1]

It would be tedious, if not impossible, to review the rôle of *four* in all the vast range of Zuñi ceremonial or mythology.[2] Let me give but a cross section of it, as it were, as it appeared to me in connection with the special subjects I was engaged in studying—the crisis ceremonial of Zuñi life, Zuñi beliefs and practises in connection with birth and growth and death.

I begin, remote as it may seem, with a rabbit hunt. But the *quadrennial* sacred rabbit hunt, the hunt with the *koko* or gods, is in an important part a phallic rite. Upon its proper performance and the correct stage-managing of the Chakwena, the Rabbit Huntress, depend the plentifulness of rabbits and of humans. *Four* days before

[1] For example, formerly after killing a Navaho all members of the expedition party were "sacred," *i. e.*, called upon to plant prayer plumes and precluded from sexual intercourse *four* days, but the actual slayer was sacred eight days, *four* days for the slain man, *four* days for himself, and the priest of the Bow was sacred twelve days, *four* days for the slain, *four* for A'hajuta, the elder war god, and *four* for himself.

[2] I may refer *passim* to Cushing, F. H., "Zuñi Creation Myths," XIII. (1891–2), *Ann. Rep. Bur. Amer. Ethnol.; Ib.*, "Zuñi Folk Tales," New York, 1901; Stevenson, M. C., "The Zuñi Indians," XXIII. (1901–2), *Ann. Rep. Bur. Amer. Ethn.* For the prominence of the same numeral among the Hopi, see Fewkes, J. W., "The Ceremonial Circuit among the Village Indians," *J. Amer. Folk-Lore*, V. (1892), 39–41.

the time set for the hunt a single rabbit is killed and its blood smeared on the legs of the Chakwena—to be rubbed off in the hunt against the plants she brushes through. For failure to catch a rabbit in the chase, *four* times a man or a "god" is struck, once on each arm and each leg. *Four* times the rabbits are run out from the surrounded areas, *four* times before the hunt turns into a secular and comparatively individualistic activity.

The hunt over, the Chakwena retires to one of the *kewitsine* or sacred club-houses,[3] where for *four* days she lies in on a warmed-up sand-bed as would a woman in her confinement, and where she is taken care of by the woman who expects by this rite of imitative magic to conceive the offspring she desires. At the close of the fourth day the would-be mother receives from the Chakwena the two ears of corn she has carried in the hunt and gives in turn to the Chakwena two other ears—*four* ears of corn figuring in that give and take.

There are other ways to promote conception, but in this connection I need refer only to the conception of twins or rather to the means taken to inhibit it. The woman who eats of the wafer bread her husband brings back with him from his deer hunt will bear twins—since the deer have twins—unless the bread is passed around the rung of her house ladder *four* times.[4]

In a real confinement the period set for it is, as in the case of the mock confinement of the Chakwena, *four* days,[5] or it may be eight days or ten or twelve—whatever the familial practise—and (this is a fact of great interest, I think) any departure from the set practise means that the mother will "dry up," get thin and die.

Were a hemorrhage to set in through the cord of the infant, it is

[3] There are *six* of them, one devoted to each of the *six* directions, north, south, east, west, the zenith and the nadir. That inspiring student of Zuñi, Frank H. Cushing, added to these directions a seventh, the middle, and seven, he stated, was a sacred number to the Zuñi. (Fewkes, p. 39, n. 2. See too Cushing, "Zuñi Creation Myths," p. 373.)

[4] *Four* figures in other connections in deer hunting. The night before the hunt eight prayer plume bundles are prepared, four for the *koko*, four for the deer.

[5] The Hopi confinement lasts four days. On the twentieth day, the day of the purifying and naming ceremonial, the "godmother" marks the house walls and floor with *four* parallel lines of meal. *Four* times she touches the head of the mother with an ear of corn dipped each time into yucca suds. The bowl in which the head is washed is thrown off the mesa after it has been waved over the spot of the lustration *four* times. In the corresponding Tewan ceremony after the mother presents the infant to the sun she turns around on the spot *four* times. (Owens, J. G., "Natal Ceremonies of the Hopi Indians," pp. 168–9, 170, 174. *J. Amer. Ethnol. and Archeology*, II. (1892).) Four days was the confinement period of the Nahuas of Mexico, the numeral being prominent in much of their ceremonialism. (Brinton, D. G., "The Myths of the New World," p. 90. New York, 1896.)

supposed that some one has been in the room who has been bitten by a dog or a snake. He would have to be found and then to save the life of the child he would have to wave some ashes over the heads of both child and mother—waving them *four* times.

Birthdays are not observed in Zuñi, but a kind of grouping by age there seems to be, for every *four* years an initiation into the *kotikili* is held and boys become eligible for this initiation some time after their first four-years age period, apparently towards the close of their second, *i. e.*, they are not initiated before they are four and they may be initiated before they are eight. In the initiation ceremonial *four* is very prominent. The ceremonial lasts *four* days, days in which the initiate fasts from meat. As he passes between the lines of the twelve *salimobi'ya,* he is whipped[6] by each masked figure *four* times.

But even before the initiation the development of Zuñi children, and, in this case, of girls,[7] as well as boys, is attended to, ceremonially. During the *watempla* dances, purificatory dances of late winter and early spring, the masks known as the *adoshlĕ* and the *suukĕ* pay domiciliary visits upon refractory children. Into the disciplinary effect of these terrifying personages we need not go, noting only that *four* times they have to advance upon a house before its adult inmates stop beating upon their pans and drums to pretend to scare them away.

Into Zuñi marriage practises *i. e.,* into a first marriage I have found no numeral obtrusion, but here my observations are by no means final. In the marriage of the widowed the favorite number does occur. Early in the morning after the couple has first slept together the second spouse gives to the remarried one something of value. This object with something belonging to himself or herself the remarried throws in the roadway. Whoever would pick these things up and appropriate them must first kick them *four* times with the left foot and then wave over the things a bit of cedar bark held in the left hand, waving it *four* times. Meanwhile the wedded pair must cut and plant their prayer plumes and stay continent,[8] *four* days for the deceased, and again cutting and planting the plumes, *four* days for themselves.

Immediately after the death of a spouse, the widowed has also planted plumes, again *four* days for the deceased and *four* days for himself or herself. *Four* days it takes the deceased to reach *kothlu-*

[6] Whipping *four* times figures in the restoration of one who has had a bad dream.

[7] Girls are seldom initiated into the *kotikili.* There are in it now *four* women and there were in it in 1902, Mrs. Stevenson reports, *four,* but the occurrence of that ubiquitous number is, in this case, I have been told, a mere fortuity.

[8] *Four* days before every plume planting and *four* days afterwards continence is required. The initiated, *i. e.*, all the men and some of the women, plant plumes every moon and on many other ceremonial occasions.

wala,[9] where live below the Sacred Lake the dead.[10] And during these *four* days the house door is left ajar, the mourners may not buy or sell, and the bowl the hair of the dead has been washed in and the implements used in digging the grave all are left out on the house top.

In the cult of the dead *four* also figures. Formerly warriors and still to-day foot racers visit the bank of the river the night before their enterprise to plant plumes in honor of the dead and to bury wafer bread. Prayer and offering made, they move back *four* steps, then sit and listen. *Four* times they thus step backwards and sit and listen.[11]

Mourning usage is ever a very conservative usage, perhaps the most unchanging of all social practises, and so I infer from the prevalence of four in it as well as from its prevalence in all the Zuñi sacerdotal rites and traditions, beds of conservatism too, that the possession of the Zuñi mind by their favorite numeral is very, very ancient.[12] Is it obsolete? I may be asked. A truly satisfactory answer would require prolonged observation. I have noted a few facts however, which suggest at least that the rule of the favorite number is not yet merely historic.

In certain accounts given a well-known ethnographer of Zuñi, accounts reliable Zuñi tell me are erroneous, the numeral four figures quite as prominently as in the unquestioned traditions or practises, *i. e.*, in freshly "made up" stories *four* still figures.[13] I too collected a tradition that shows on its face a comparatively recent origin, a tradition of tribal origins. First to come up into the world, I was told, were the Pimas, the Navaho, the Moki and the peoples of other pueblos, then came the Mexicans, then the "Americans," *fourthly* the Ashiwi or Zuñi.[14] Again in the Zuñi sheep brand, a comparatively late *in-*

[9] The death trip takes this time among many American tribes. (Brinton, p. 90.)

[10] Zuñi who have represented the *koko* live after death in a hill-side, in a *four*-roomed dwelling. To the Sacred Lake southwest of Zuñi a *quadrennial* ceremonial journey is made.

[11] If they hear sounds of the river roaring or of an owl hooting or of lips smacking or of horse hoofs, it is well. To hear nothing is not well.

[12] Its prominence among the other pueblos would indicate too that it had asserted itself in the matrix pueblo culture, if not, given its prominence likewise in many American tribes, in a still more ancient culture.

[13] An infant's skin is rubbed with ashes to depilitate it but no trace of evidence of belief that exfoliation occurs within *four* days could I find. Cp. Stevenson, "The Zuñi Indians," p. 300 n. b. The statement that the forbidden sight of the Sacred Lake will cause visions and death I verified, but the further statement that the death would result in four days (see *Ib.*, p. 356)—this statement was denied. Nor is it believed that the dead live in a house in *kothluwala* containing *four* windows. It were tiresome to continue this list.

[14] This fourth emergence from the Sacred Lake, let me note incidentally, greatly pleased the Sun, because now at least on earth were some to talk his language.

vention, I'm justified in seeing, I think, the use or influence of four. Again, twice during the lifetime of my elderly informant has a Priest of the Bow attempted to establish an innovation[15] in pottery making, relegating and limiting its making to the ceremonial *four* days of the summer solstice,[16] the firing of all the ware to take place on the *fourth* day.

But one striking modern breakdown in the rule of four I did find. The governor of Zuñi, the lieutenant governor and the members of their staffs, their *tenientes* as they are called, no longer make up a board of eight. The three *tenientes* under the governor have been increased first to four then to five, the three under the lieutenant-governor, to four, increases the *practical* needs of government have in recent years required.[17] But the procedure of the board continues, let me add, unchanged. Adjudications are not made by the governor until each *teniente* has in turn made his suggestions and each makes them *four* times.

In conclusion let me give the answers I got when I asked, "Why four?" The first was given me by a Rain priest. "Because," he said, "when the people came up into the world at *kothluwala* they stayed there *four* time periods and as they moved about later they always stayed *four* time periods in each place." The explanation called to mind that offered by another people of early culture for their own sacred number, the number seven. The second answer to my query was given me by a medicine-man of the *Ne'wekwe* Fraternity. "Why four? Because," he said, "the Americans do not always speak the truth. They will give any number. But the Zuñi speak the truth and so they give the true number, the number *four.*" Would it not be difficult to get a better illustration of how number may indicate subjective states of mind rather than objective circumstances?

[15] Compare Stevenson, "The Zuñi Indians," p. 150. One of these periods must have occurred while Mrs. Stevenson lived in Zuñi. The custom my informant declared an innovation, an innovation lasting only while its sponsor, the Bow Priest, lived, may have been of course the revival by him of an ancient custom.

[16] During these days none buys or sells or indulges in sexual intercourse. During the first *four* days of the winter solstice ceremonial members of fraternities and the *ashiwani* or rain priests and their households may not buy or sell or eat salt or meat or grease. For *ten* days none may carry out refuse of any kind from a house.

[17] Of interest in this connection is the moot question whether or not these officials are Spanish made. They were—at the close of the seventeenth century—according to Cushing. ("Zuñi Creation Myths," p. 332.)

THE ORIGIN AND EVOLUTION OF LIFE ON THE EARTH

By HENRY FAIRFIELD OSBORN

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LECTURE II PART II

EVOLUTION OF THE FISHES

FOLLOWING the pro-fishes of Odrovician time (p. 508) the great group of fishes begins its evolution with (*A*) active, free-swimming, double pointed types of fusiform shape, adapted to rapid motion through the water and to predaceous habits in pursuit of swift-moving prey. From this type there radiated many others: (*B*) the deep, narrow-bodied fishes of relatively slow movements, frequenting the middle

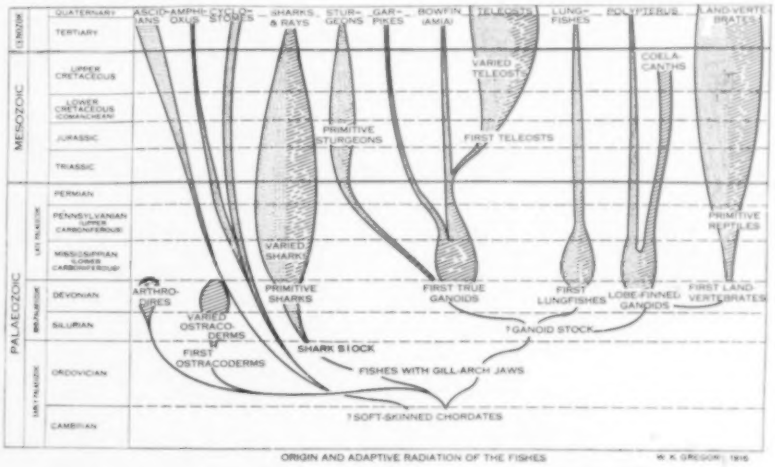


FIG. 9*a*. ORIGIN AND ADAPTIVE RADIATION OF THE FISHES SHOWING THE NOW EXTINCT SILURO-DEVONIAN GROUPS, the Ostracoderms and Arthrodires, in relation to the surviving lampreys (Cyclostomes), sharks, and rays (Elasmobranchs), sturgeons, garpikes, bowfins (Ganoids), bony fishes (Teleosts), primitive and recent lung-fishes (Dipnoi), and finally the fringe-finned Ganoids (Crossopterygii) from the cartilaginous fins of which the fore and hind limbs of the first land-living vertebrates (Tetrapoda) were derived. Dotted areas represent groups which still exist. Hatched areas represent extinct groups. Prepared for the author by Wm. K. Gregory.

depths of the waters; (*D*) the swift-moving, elongate types which increasingly depended upon lateral motions of the body for propulsion and thus tended to lose the lateral fins and finally to assume an elongate, eel shape entirely finless; (*C*) other bottom-living forms in which the body became laterally flattened, the head very large relatively and covered with protective dermal armature, the movements of the animals very slow.

Smith Woodward[6] has traced similar radiations of body form in the historic evolution of each of the great groups of fishes.

The importance of this law of form radiation is greatly enhanced

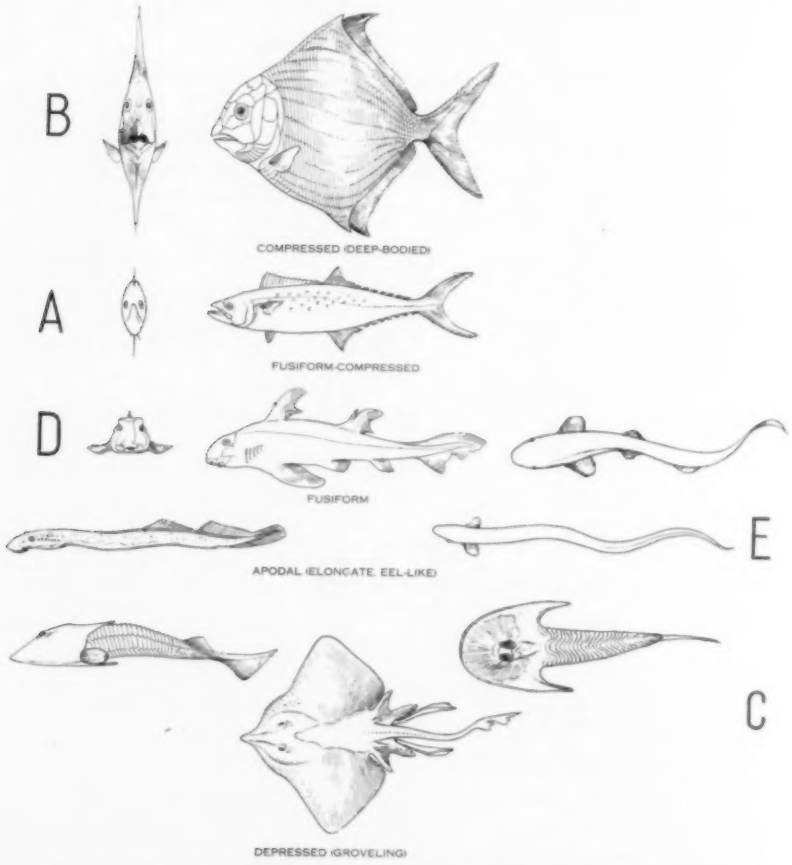


FIG. 9b. THE FIVE PRINCIPAL TYPES OF BODY FORM IN FISHES, beginning with (*A*) the swift-moving, compressed, fusiform types which pass, on the one hand, into (*B*) the compressed, slow-moving, deep-bodied types, and, on the other, into (*C*) laterally depressed, round, bottom-dwelling, slow-moving types, also into (*D*) elongate, swift-moving, fusiform types which grade into (*E*) the eel-like and swift-moving, bottom-living types without lateral fins. These five types of body form in fishes independently arise over and over again in the various groups of this Order. Partially parallel forms also appear among the Amphibia, Reptilia, and Mammalia. Prepared for the author by Wm. K. Gregory and Erwin S. Christman.

when we find it repeated successively among the aquatic Amphibia, Reptilia and Mammalia as one of the invariable effects of the *coordination of the mechanism of motion with that of offense and defense.*

[6] Smith Woodward, A., "The Use of Fossil Fishes in Stratigraphical Geology," *Proc. Geol. Soc. of London*, Vol. LXXI., Pt. 1, 1915, pp. lxii–lxxv.

In each of these four or five great radiations of form, from the swift-moving to the bottom- or ground-living, slow, armored types, there is usually an increase of bodily size, also an increase of specialization, the maximum in both being reached just before the period of extinction arrives.

The Ordovician Ostracoderms are very little known. The Upper Silurian Ostracoderms enjoyed a wide distribution in Europe and America. They include both the fusiform free-swimming type (*Birkenia*) and the depressed ray-like types (*Lanarkia*, etc.). They apparently had not yet acquired cartilaginous lower jaws and appear to be in a lower stage of evolution than the true fishes. The armature is arranged in shield and plate form in *Palæaspis*, from the Upper Silurian Salina time of Schuchert, where we obtain our first glimpse of North American land life in the presence of the oldest known air-breathing animals, the scorpion spiders, and also the first known land plants. There are many indications of an arid climate. In Upper Silurian

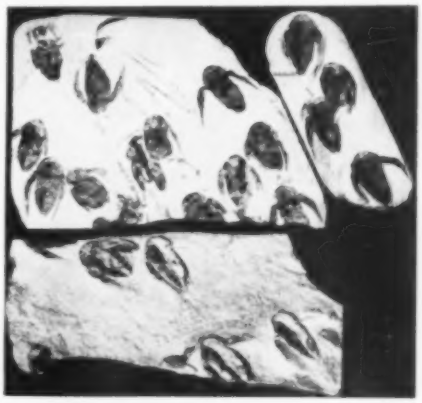


FIG. 10. ARMORED, BOTTOM-LIVING OSTRACODERM TYPE, *Bothriolepis*, from the Upper Devonian of Canada, with chitinous armature and a pair of anterior appendages analogous to those in Eurypterids. This cluster of animals was undoubtedly buried simultaneously while headed against the current either in search for food or for purposes of respiration. After Patten, *op. cit.*

FIG. 11. THE *Palæaspis* OF CLAYPOLE AS RESTORED BY DEAN.

time the Ostracoderms reach the slow, armored, bottom-living stage of evolution, as typified in the Pteraspidians and Cephalaspidians, which were widely distributed in Europe, in America, and possibly in the Antarctic regions, as indicated by recent explorations there. Belonging to a *very distinct order* or subclass (Antiarchi) are certain armored Devonian forms (*Bothriolepis, Pterichthys*, etc.), which possessed a pair of jointed lateral appendages. Propelled by a pair of appendages attached to the anterior portion of the body; some of these animals (*Bothriolepis*) present analogies to the eurypterids (Merostomata, or Arachnida).

In the freshwaters of the Lower Devonian have been discovered the

ancestors of the heavily armored fishes known as the Arthrodira, a group of uncertain relationships. They have many characters in common with *Bothriolepis* (joint-neck, dermal jaws, carapace and plastron, paired appendages (*Acanthaspis*)). Dean, Hussakof and others regard the balance in favor of relationship with the stem of the Antiarchi (*Bothriolepis*). In the Middle Devonian (the Cleveland shales of Ohio) they attain the formidable size shown in the species *Dinichthys intermedius*. Like the Ostracoderms these animals are not central or in the main lines of fish evolution but represent collateral lines which early attained a very high degree of specialization followed by extinction.

FIG. 12. RESTORATION OF THE GIGANTIC MIDDLE DEVONIAN ARTHRODIRAN (JOINTED NECK) FISH *Dinichthys intermedius*, EIGHT FEET IN LENGTH, OF THE CLEVELAND SHALES (OHIO), showing the bony teeth and bony armature of the head region. Lateral view of the same model in the American Museum of Natural History. Model by Dr. Louis Hussakof and Mr. Horter.

The central line of fish evolution is found in the typical cartilaginous skeleton and jaws and four fins of the primordial sharks, the primitive fusiform stage of which appears in the spine-finned type (Acanthodian) of Upper Silurian time. The relatively large-headed, bottom-living types of sharks do not appear until the Devonian, during which epoch the early swift-moving, fusiform predaceous types branch off into the elongated eel-shaped forms of the Carboniferous. The prototype of the shark group is the *Cladoselache*, a fish famed in the annals of comparative anatomy since it demonstrates that the fins of fishes arise from lateral skin folds of the body with internal stiffening cartilaginous rods (Fig. 13), which in course of evolution are concentrated to form the central axis of a freely jointed fin, while in a further step of evolution they transform into the cartilages and bones of the limb girdles and limb segments of the four-footed land vertebrates (Tetra-

poda). The manner of this transformation has been one of the greatest problems in the solution of the origin of animal form since the earliest researches of Carl Gegenbaur of Heidelberg, who sought to derive the lateral fins from modification of the cartilaginous rods supporting the gills, through a profound change of function. While paleontology has disproved Gegenbaur's hypothesis that the limbs of the higher vertebrates, including those of man, are derived from the gill arches of fishes, it has helped to demonstrate the truth of Reichert's hypothesis that the bony chain of the middle ear of man has been derived through change of function from a portion of a modified gill arch (mandibular cartilage) of the fish.

The cycle of shark evolution in course of geologic time embraces a majority of the swift-moving, predaceous types, which branch into the sinuous, elongate body of the frilled shark (*Chlamydoselache*) and into forms with broadly depressed bodies such as the bottom-living skates and rays. Under the law of adaptive radiation the sharks seek every possible habitat zone in the search for food. The nearest approach to the eel-shaped type among the sharks are certain forms discovered in Carboniferous time. By Upper Devonian time the fishes in general had already radiated into all the great existing groups. The primitive armored Arthrodires and Ostracoderms were nearing extinction. The sharks were still in the early lappet-fin stage of evolution above described, a common characteristic of the family being that they never evolved a bony armature. The scaled armature of the first true Ganoid fishes (*Osteolepis, Cheirolepis*) makes its first appearance. These armored knights of the sea are related to simpler forms which gave rise to the rich stock of sturgeons, garpikes, bow-fins, and true bony fishes (Teleosts) which now dominate all other fish groups both in the freshwaters and the seas. Close to this stock are the first lung fishes (Dipnoi), represented by *Dipterus;* also the "lobe-" or "fringe-finned" Ganoids from which the first land vertebrates were derived. From a single locality, in the Old Red Sandstone of Scotland, Traquair has

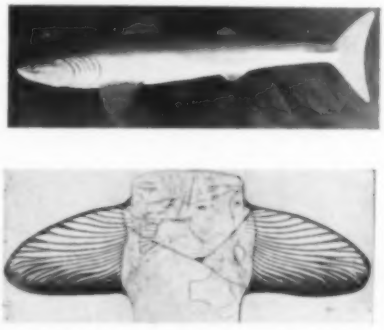


FIG. 13. (UPPER.) *Cladoselache*, THE TYPE OF THE PRIMITIVE DEVONIAN SHARK OF OHIO WITH PAIRED AND MEDIAN FINS PROVIDED WITH ROD-LIKE CARTILAGINOUS SUPPORTS, from which type by fusion the limbs of all the higher land vertebrates have been derived. Model by Dean, Hussakof and Horter from specimens in the American Museum of Natural History.

(LOWER.) THE LAPPET FINS OF *Cladoselache* SHOWING THE CARTILAGINOUS RAYS (WHITE) WITHIN THE FIN (BLACK). After Dean.

recovered a whole series of these archaic fish types as they lived together in the fresh water or the brackish pools of Upper Devonian time. (Fig. 14.)

In this period the paleogeographers (Schuchert) obtain their first evidence of the evolution of the terrestrial environment in the indica-

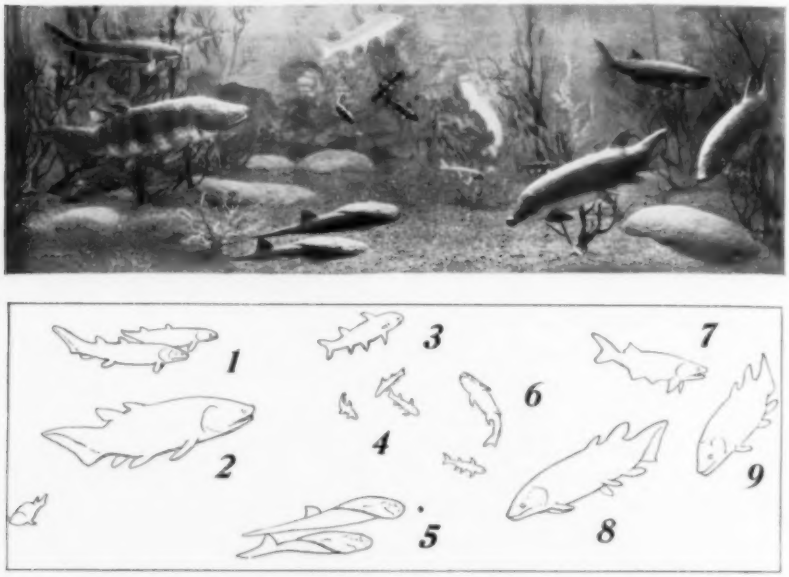


FIG. 14. FISH TYPES OF THE OLD RED SANDSTONE OF SCOTLAND. UPPER DEVONIAN TIME. PRIMITIVE GANOIDS (*Osteolepis, Cheirolepis*), primitive spine-finned sharks, Acanthodians (*Diplacanthus*), bottom-living Ostracoderms (*Pterichthys*), first lung fishes (*Dipterus*), partly armored Ganoids (*Holoptychius*). 1, *Osteolepis*, primitive lobe-finned Ganoid. 2, *Holoptychius*, fringe-finned Ganoid. 3, 6. *Cheiracanthus*, spine-finned shark (Acanthodian). 4, *Diplacanthus*, spine-finned shark (Acanthodian). 5, *Coccosteus* primitive Arthrodiran. 7, *Cheirolepis*, primitive Ganoid. 8, 9, *Dipterus*, primitive lung fish. 10, *Pterichthys*, bottom-living Ostracoderm allied to *Bothriolepis*. Models in the American Museum of Natural History, restorations by Dean, Hussakof and Horter, partly after Traquair.

tions of the existence of parallel mountain ranges on the British Isles, of active volcanoes in the Gaspé region of New Brunswick, in the mountain formations of South Africa, and in the depressions of the center of the Eurasiatic continent into the great central Mediterranean sea, the *Tethys* of Suess. In the seas of this time as compared with Cambrian seas we observe that the trilobites are in a degenerate phase, the brachiopods are relatively less numerous, the echinoderms are represented by the bottom-living starfishes, the sharks are abundant, the Arthrodiran fishes are still abundant in Germany.

It was long believed that the Amphibia evolved from the Dipnoi, the air-breathing fishes of the inland fresh waters, and this hypothesis was stoutly maintained by Carl Gegenbaur, who upheld what he termed

the Archipterygian theory of the origin of the limb, seeking the prototype of the modern limbed forms in the fin of the modern Australian lung fish, *Ceratodus*. This hypothesis of Gegenbaur, warmly supported by a talented group of his students, is memorable as the last of the great hypotheses regarding vertebrate evolution founded exclusively

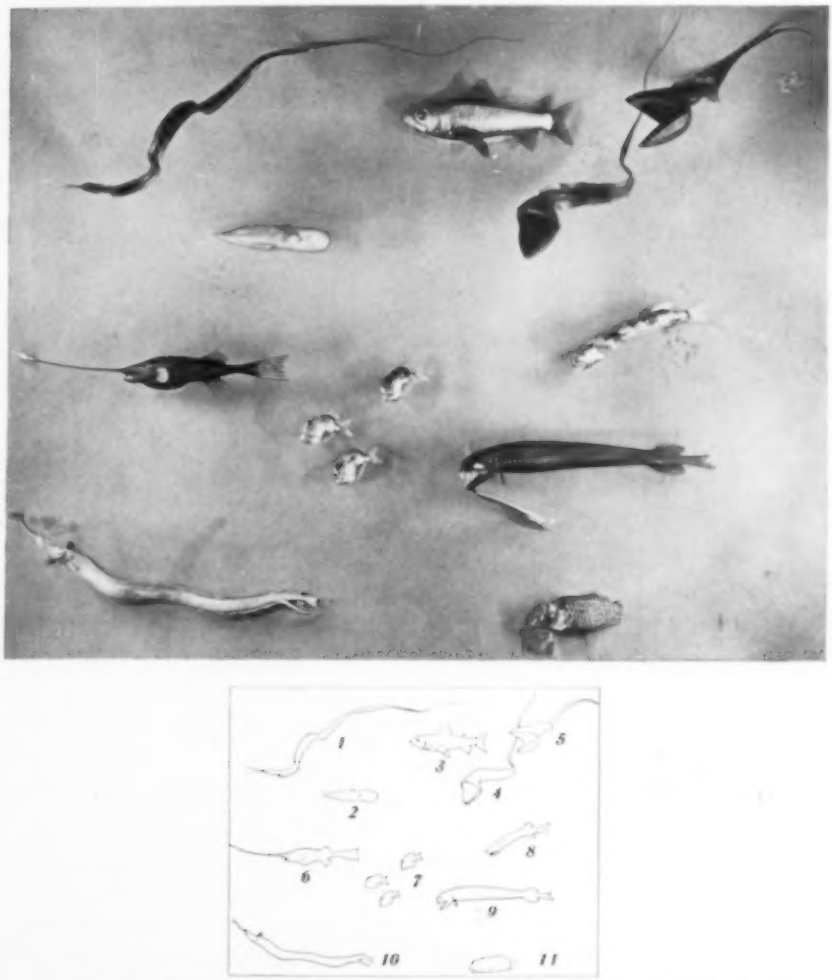


FIG. 15. THE EXTREMES OF ADAPTATION IN MOTION AND ILLUMINATION IN THE EXISTING BONY FISHES (TELEOSTS) OF THE ABYSSAL REGIONS OF THE OCEANS. Although many different orders of Teleosts are represented each type has acquired phosphorescent organs, affording a fine example of convergence. The body form is of great diversity.

1, Thread-eel, *Nemichthys scolopaceus* Richardson. 2, *Barathronus diaphanus* Brauer. 3, *Neoscopelus macrolepidotus* Johnson. 4, 5, *Gastrostomus bairdi* Gill and Ryder. 6, *Gigantactis vanhoeffeni* Brauer. 7, *Sternoptyx diaphana* Lowe. 8, *Giganturа chuni* Brauer. 9, *Melanostomias melanops* Brauer. 10, *Stylophthalmus paradoxus* Brauer. 11, *Opisthoproctus solcatus* Vaillant.

upon comparative anatomy and embryology as opposed to the triple evidence afforded by these sciences when reenforced by paleontology.

It is through the discovery of primitive types of the fringe-finned ganoids, to which Huxley gave the appropriate name Crossopterygia, that the true ancestry of the Amphibia and of the amphibian limb has

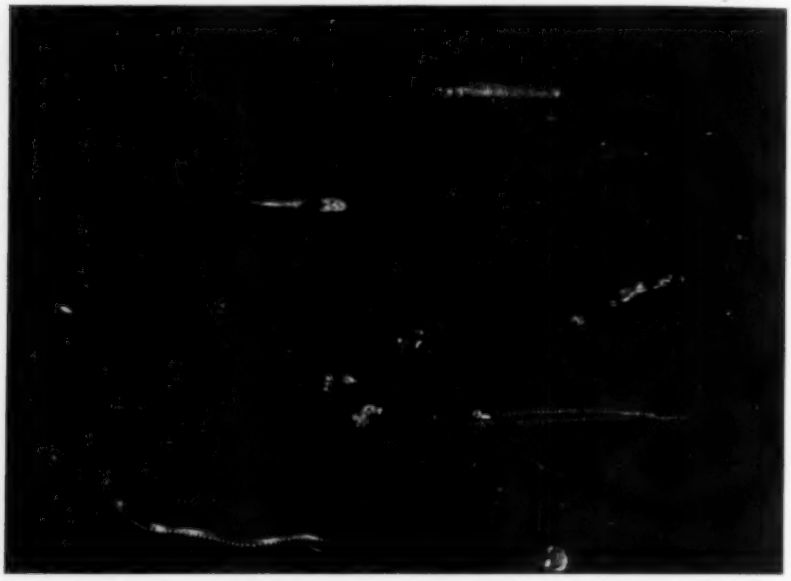


FIG. 16. PHOSPHORESCENT ILLUMINATING ORGANS OF THE ABYSSAL FISHES REPRESENTED IN FIG. 15, as they are supposed to appear in the darkness. After models in the American Museum of Natural History.

been traced, as due to a partial change of function whereby the propelling fin was gradually transformed into the propelling limb. This implies a long terrestrio-aquatic phase in which the fin was partly used for propulsion on muddy surfaces (Fig. 17). In the parallel retrogressive evolution of the lung fishes (*Lepidosiren, Gymnotus*) the fringe-finned fishes (*Calamoichthys*) and the bony fishes (*Anguilla*) the final eel-shaped, finless stage is either approached or actually passed.

The bony fishes (Teleosts), which first emerge as a distinct group in Jurassic time, radiate adaptively into all the great body types attained by the older groups, more or less closely imitating each in turn, so that it is not easy to distinguish superficially between the armored catfishes (*Loricaria*) of the existing South American waters and their prototypes (*Cephalaspis*) of the early Paleozoic. The most extreme specialization in this great group is to be found in the radiations of abyssal fishes into slow- and swift-moving forms inhabiting the great depths of the ocean, adapted to tons of water pressure, to temperatures

just above the freezing point, and to total absence of light which is compensated for by the evolution of a great variety of phosphorescent light producing organs.[7] Another extreme of chemical evolution among

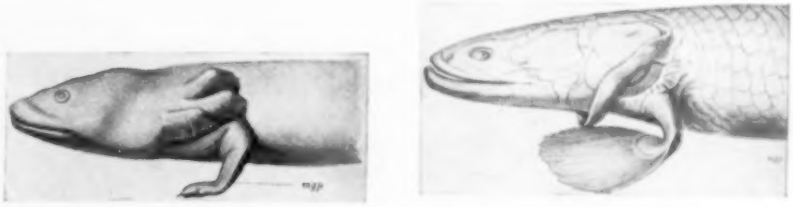


FIG. 17. THEORETIC MODE OF CONVERSION OF THE LOBE-FIN OF THE FISH (RIGHT) INTO THE FOOT OF AN AMPHIBIAN (LEFT) through loss of the dermal fringe border and rearrangement of the cartilaginous supports of the lobe. After Klaatsch.

the fishes is the production of electricity as a protective function, which is even more effective than bony armature because not interfering with rapid motion. In only a few of the fishes is electricity generated in sufficient amounts to thoroughly protect the organism. It develops through modified body tissues in the form of superimposed plates

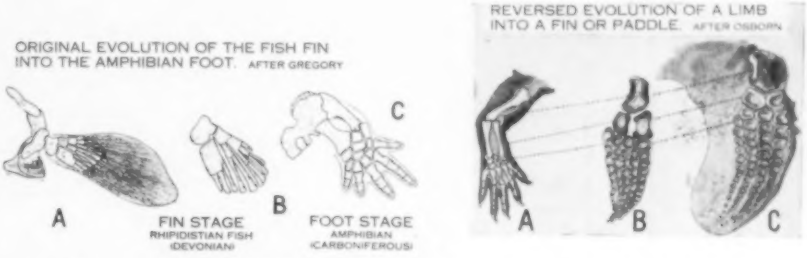


FIG. 18. (LEFT.) DIRECT ORIGINAL EVOLUTION OF THE BONES OF THE LOBE-FIN OF A FISH (*A*, *B*) (*Rhipidistia* type of Cope) into the bony, five-rayed limb (*C*) of the Amphibian of the Carboniferous age.

(RIGHT.) SECONDARY REVERSED EVOLUTION OF THE FIVE-RAYED LIMB OF A LAND REPTILE (*A*) into the fin, or paddle (*B*, *C*) of an ichthyosaur.

(electroplaxes) separated equally from one another by layers of a peculiar jelly-like connective tissue, all lying parallel to each other and at right angles to the direction of discharge. The electric organ is formed from modified muscle and connective tissue and is innervated by motor nerves. The physical principle involved is that of the concentration cell, and the electrolyte used in the process is probably sodium chloride. The theory is that at the moment of discharge a membrane is formed on one surface of the electroplax which prevents the negative ions from passing through while the positive ions do pass

[7] The author is especially indebted to Professor Ulric Dahlgren, of Princeton University, for notes upon phosphorescent and electric organs.

through and form the current. The strength of the current varies from four volts in *Mormyrus* up to as much as 250 or more in *Gymnotus*, the electric eel, and consists of a series of shocks discharged 3/1000 of a second apart.

EVOLUTION OF THE AMPHIBIA

A single impression of a three-toed footprint (*Thinopus antiquus*) in the Upper Devonian shales of Pennsylvania constitutes at present the sole paleontologic proof of the period of transition from the fish

FIG. 19. FOOTPRINT OF *Thinopus antiquus* MARSH, THE EARLIEST KNOWN LIMBED ANIMAL, an Amphibian from the Upper Devonian of Pennsylvania. Type in the Peabody Museum of Yale University. Photograph of cast presented to the American Museum by the Peabody Museum.

FIG. 20. THE TYPE OF SALAMANDER-LIKE PRIMITIVE AMPHIBIAN OF UPPER DEVONIAN TIME (*Pentadactyloidea, Tetrapoda*), with large, solidly roofed skull, four limbs, and five fingers on each of the fore and hind feet. After Fritsch.

type to the amphibian type. This took place in Lower Devonian if not in Upper Silurian time. The adaptive radiation of these primordial Amphibia probably began in Middle Devonian time and extended through the great swamp, coal-forming period of the Carboniferous, which afforded over vast areas of the earth's surface ideal conditions for amphibian evolution, the stages of which are best preserved in the Coal Measures of Scotland, Saxony, Bohemia, Ohio and Pennsylvania, and have been revealed through the studies of von Meyer, Owen, Fritsch, Cope, Credner and Moodie. The earliest of these terrestrio-aquatic

types have not only a dual breathing system of gills and lungs but a dual motor equipment of limbs and a propelling median fin in the tail region.

So far as known primordial Amphibia in body form were chiefly of the small-headed, long-bodied, small-limbed, tail-propelled type of the modern salamander and newt. The large-headed, short-bodied types (*Amphibamus, Pterophlax*) were primitive. In Upper Carboniferous and early Permian time the terrestrial forms began to be favored by the land elevation and recession of the sea which distinguished the close of the Carboniferous and early Permian time. Under these varied zonal

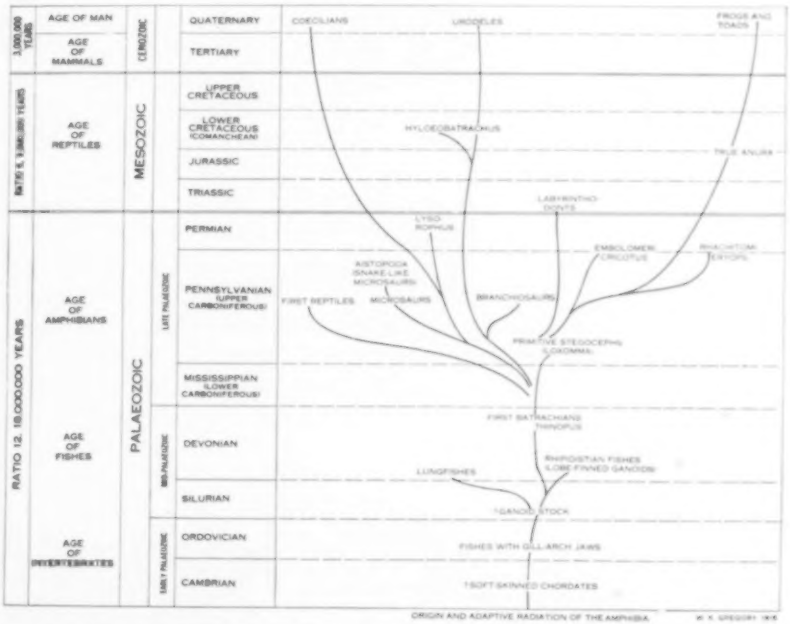


FIG. 21. DESCENT OF THE AMPHIBIA IN WHICH THE FIN IS TRANSFORMED INTO A LIMB (*Thinopus*), from an ancestral Ganoid fish stock of Silurian age through the fringe-finned Ganoids. From this group diverge the ancestors of the Reptilia and the salamander-like Amphibians which give rise to the various salamander types, also to branches of limbless and snake-like forms (*Aistopoda*, modern Cœcilians). The other great branch of the solid-skulled Amphibia, the Stegocephala, was widespread all over the northern continents in Permian and Triassic time (*Cricotus, Eryops*), and from this stock descended the modern frogs and toads (*Anura*). Prepared for the author by Wm. K. Gregory.

conditions, aquatic, palustral, terrestrio-aquatic, fossorial and terrestrial, the Amphibia radiated into several habitat zones and adaptive phases, thus recapitulating all the chief types of body form which had previously evolved among the fishes and anticipating many of the types of body form which were to evolve among the Reptilia. One ancestral feature is a layer of superficial body scales derived from those of their

fringe-finned fish ancestors; with the loss of these scales most of the Amphibia also lost the power of forming a bony dermal armature.

Recent researches in this country, chiefly by Williston and Case, indicate that the solid-headed Amphibia (Stegocephala) and primary forms of the Reptilia chiefly belong to late Carboniferous (Pennsylvania) and early Permian time. They are found abundantly in pool deposits widespread over the southwestern United States and Europe associated in rocks of a reddish color, which point to aridity of climate in the northern hemisphere during the period in which the terrestrial adaptive radiation of the Amphibia occurred. These arid conditions continued during the greater part of Permian time, especially in the northern hemisphere. In the southern hemisphere there is evidence even of a period of extensive glaciation, which was accompanied by the disappearance of the old lycopod flora (club mosses) and arrival of the cool fern flora (*Glossopteris*) which appeared simultaneously in South America, South Africa, Australia, Tasmania and southern India. The widespread distribution of this flora in the southern hemisphere furnishes one of the arguments for the existence of the great South Pacific continent *Gondwana,* a hypothesis of Suess which is supported by Schuchert. In North America Permian glaciation was only local. The last of the great Paleozoic seas disappeared from the surface of the continents, while the border seas give evidence of the rise of the ammonite cephalopods. Toward the close of Permian time the continent was completely drained. Along the eastern seaboard the Appalachian revolution occurred, and the mountains rose to heights estimated at from three to five miles.

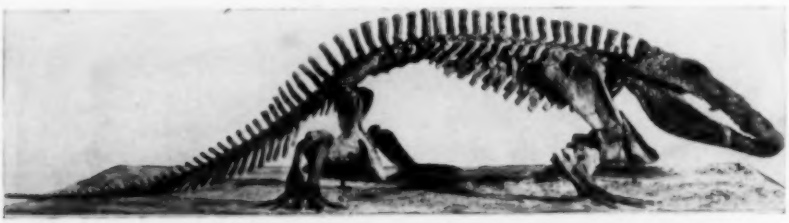


FIG. 22. SKELETON OF *Eryops* FROM THE PERMO-CARBONIFEROUS OF TEXAS, type of the stegocephalian Amphibians which were structurally ancestral to the Labyrinthodonts of the Triassic. Mounted in the American Museum of Natural History.

Evidences of extensive continental connections in the northern hemisphere are found in the community of type between the great terrestrial amphibians of such widely separated areas as Texas and Württemberg which develop into similar resemblances between the great Labyrinthodont amphibians of Lower Triassic times of Europe, North America and Africa. Ancestral to these Triassic giants is the large, sluggish, water- and shore-living *Eryops* of the Texas Permian, with

massive head, depending on its short, powerful limbs and broad, spreading feet for land propulsion and in a less degree upon its tail for pro-

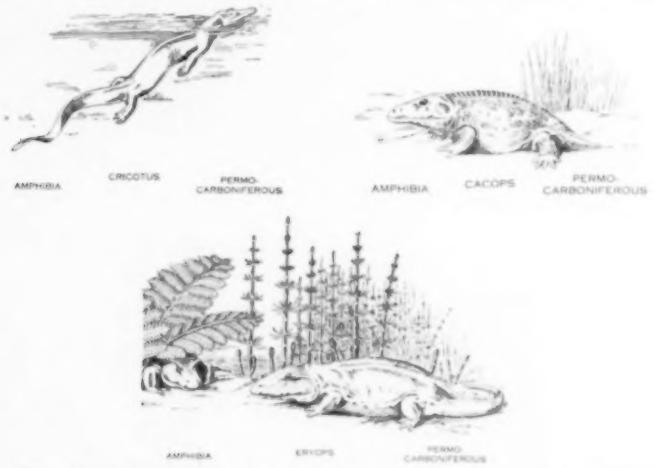


FIG. 23. AMPHIBIA OF THE AMERICAN PERMO-CARBONIFEROUS, the free-swimming *Cricotus*, short-bodied *Caccops*, and continuation of the amphibious short-tailed terrestrial type, the large, solid-headed *Eryops*. Restorations for the author by Gregory and Deckert.

pulsion in the water. This form may be a collateral ancestor of the Labyrinthodonts; it belongs to a type which spread all over Europe and North America and persisted into the *Metopias* of the Triassic.

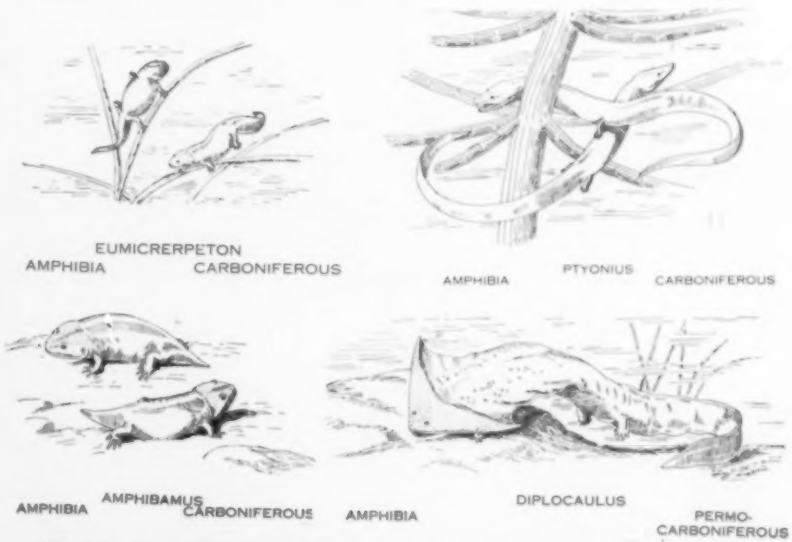


FIG. 24. CHIEF AMPHIBIAN TYPES OF THE CARBONIFEROUS, the early short-tailed, land-living *Amphibamus*, the salamander-like *Eumicrerpeton*, the eel-bodied *Ptyonius*, the broad-headed, bottom-living *Diplocaulus*. Restorations for the author by Gregory and Deckert.

An opposite extreme of slender body structure is found in the active predaceous types of water-loving amphibians such as *Cricotus*, of rapid movements, propelled by a long tail fin and with sharp teeth adapted to seizing an actively moving prey. This type retrogresses into the eel-like, bottom-loving *Lysorophus* with its slender skull, elongate body propelled by lateral swimming undulations, the limbs relatively useless. Corresponding to the bottom-living fishes are the large, sluggish, broad-headed, bottom-living amphibians, such as *Diplocaulus*, with heads heavily armored, limbs small and weak, the body propelled by lateral

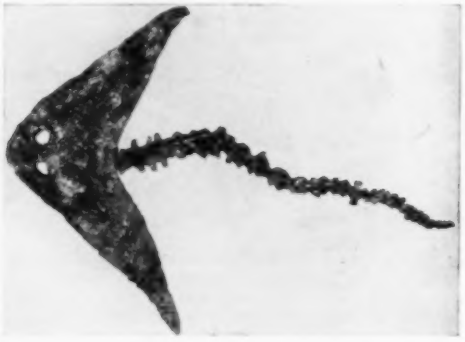


FIG. 25. SKULL AND VERTEBRAL COLUMN OF *Diplocaulus*, a typical solid-, broad-headed Amphibian from the Permian of northern Texas. Specimen in the American Museum of Natural History.

motions of the tail. There were also more powerful, slow-moving, long-headed, alligator-like, terrestrio-aquatic forms, such as the *Archegosaurus* of Europe and the fully aquatic *Trimerorachis* of America. An extreme stage of terrestrial, ground-living evolution with marked reduction of the use of the tail for propulsion is the large-headed *Caccops*, short-bodied, with limbs of medium size, but with feeble powers of prehension in the feet. Radiating around these animals were a number of terrestrial types exhibiting the evolution of dorsal protective armature and spines (*Aspidosaurus*); other types lead into the pointed-headed structure and pointed teeth of *Trematops*.

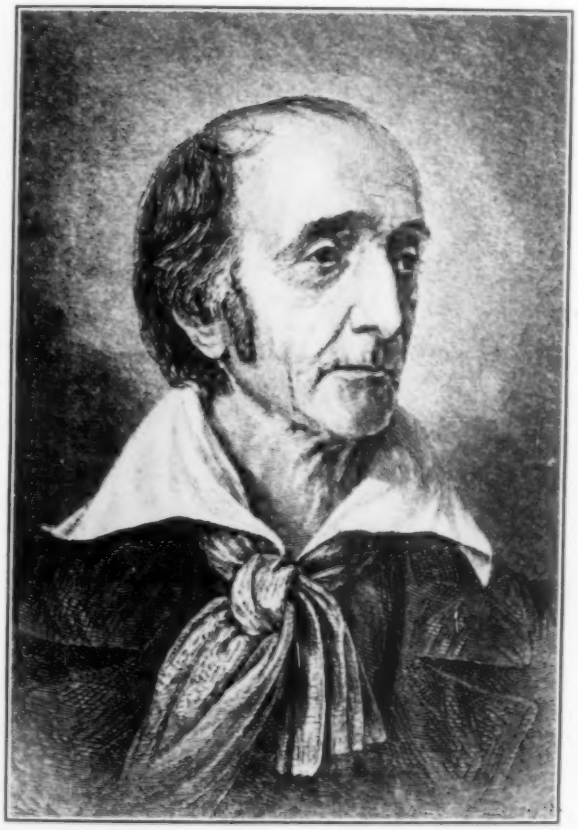
Editorial Note: The remaining parts of this Lecture will appear in December or January in book form under the title "Origin and Evolution of Life," from the press of Charles Scribner's Sons.

THE PROGRESS OF SCIENCE

THE UNITED STATES COAST AND GEODETIC SURVEY AND ITS EARLY SUPERINTENDENTS

THE centenary of the organization of the United States Coast and Geodetic Survey was fittingly celebrated in Washington last spring and the proceedings have now been issued in a volume which forms an interesting memorial of the celebration and of the great work accomplished by the survey since its foundation in 1816. The program consisted of three public sessions and a dinner. The former were held in the auditorium of the New National Museum, where fifteen addresses were given on the different phases of the survey's activities and on the relation of its work to other scientific bureaus of the government.

The superintendent of the survey, Mr.



FERDINAND RUDOLPH HASSLER.

E. Lester Jones, presided at the public sessions, and the opening address was made by Mr. William C. Redfield, secretary of commerce, the department of which the survey is now a bureau. At the banquet the president of the United States made one of the addresses. Others were by the secretary of the navy, the secretary of commerce, the minister from Switzerland, and the former superintendent of the survey, Dr. T. C. Mendenhall.

The address of Dr. Mendenhall and some of the other addresses give interesting reminiscences of the early work of the survey and its first three superintendents, portraits of whom are here reproduced by the courtesy of the superintendent of the survey. Ferdinand Hassler, born in Switzerland, trained in the best schools of Europe and practised in geodetic work, came to the United States in 1805, bringing with him a fine library of over 3,000 volumes and a collection of technical instruments such as had never before crossed the ocean. He was later appointed acting professor of mathematics at West Point and, through his friend and countryman, Albert Gallatin, was introduced to Jefferson, who had recommended to the Congress a survey of the coasts. Hassler demanded and received a salary equal to that of the head of the department to which the new bureau was assigned. It is said that the president objected, saying "your salary would be as large as that of my secretary of the treasury, your superior officer," and that he replied: "Any president can make a secretary of the treasury but only God Almighty can make a Hassler."

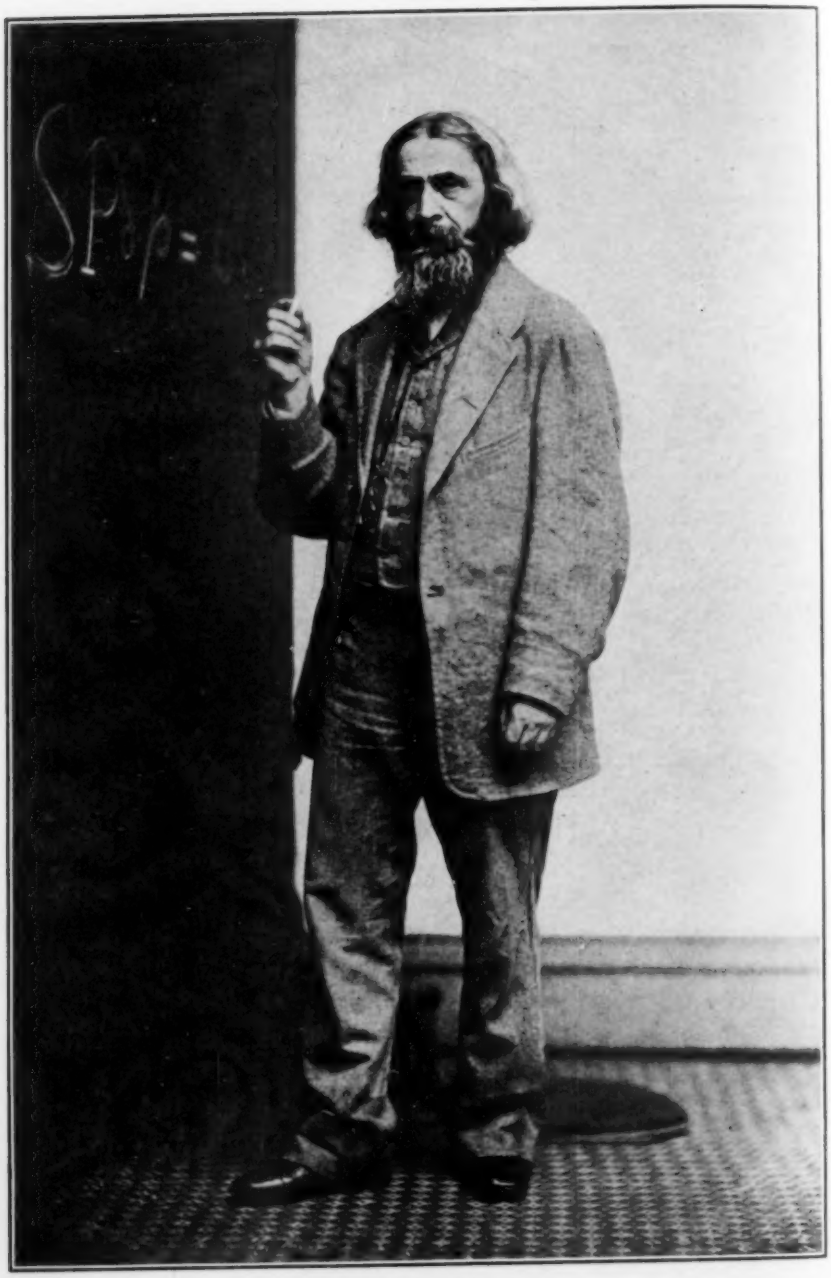
Hassler was sent abroad in 1811 to purchase the necessary instruments and standards of measurement but was detained in England as an alien enemy. When he returned, in 1816, the Coast and Geodetic Survey was organized, and geodetic, topographic and hydrographic work was begun. Owing to lack of appropriations by Congress, work was abandoned for twelve years, when Hassler was placed in charge of work on weights and measures, and in 1832 again assumed the duties of superintendent of the survey, which he conducted with admirable skill until his death in 1843.

Hassler was succeeded as head of the survey by Alexander Dallas Bache, a great grandson of Benjamin Franklin, whose scientific aptitudes and diplomatic skill he inherited. Graduating from the West Point Military Academy, he had attained distinction as a scientific man of originality and power, and was recommended as Hassler's successor by the scientific societies and institutions of learning. His services were continued for twenty-five years until his death in 1867; they carried forward and enlarged in important directions the work begun by Hassler.

Benjamin Peirce, the distinguished mathematician, who had conducted the longitude operations of the survey during the latter years of Bache's administration, succeeded him as superintendent, a position which he held until the age of sixty-five years, while retaining his professorship at Harvard University. The picture of Peirce shows him at the blackboard. He is said once at a meeting of the National Academy of Sciences to have spent an hour filling the blackboard with equations, and then to have remarked "There is only one member of the Academy who can understand my work and he is in South America." Under Peirce a chain of triangles extending across the continent was planned covering the whole country by a trigonometrical survey and joining the systems of the Atlantic and Pacific coasts.

We may hope that the next three superintendents of the Coast and Geodetic Survey will be men so distinguished in science as Hassler, Bache and Peirce. If this is not the case we should surely enquire into the reason. Is it because the men do not exist, or are we less competent to manage the scientific bureaus now than was the case in the earlier part of the nineteenth century? We can not believe that the human germ plasm has changed in the

ALEXANDER DALLAS BACHE.



BENJAMIN PEIRCE.

course of two or three generations, and if we do not have the men, it is because we do not select and train them. It is equally our fault if such men are not placed in charge of the scientific work of the government.

THE NEW YORK MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE first of the greater convocation-week meetings of the American Association for the Advancement of Science and its affiliated societies will be held in New York City during the last week of the present month. It has been arranged that there will be held hereafter once in four years successively in New York, Chicago and Washington, meetings at which it is planned to bring together all the national scientific societies and, so far as possible, all the scientific men of the country. There will meet in New York, counting the sections of the association, more than fifty separate organizations devoted to the advancement of science, and there has not been in the history of the world a meeting of this magnitude. When the association last met in New York City ten years ago there were about five thousand members, the attendance was over two thousand, and there were nearly a thousand papers on the program. The present membership of the association numbers about eleven thousand, and the number and size of the affiliated societies has increased in proportion.

The opening session, presided over by Dr. Charles R. Van Hise, of the University of Wisconsin, will be held at the American Museum of Natural History on the evening of December 26, at which time the address of the retiring president, Dr. W. W. Campbell, director of the Lick Observatory, on "The Nebulæ" will be delivered. The registration headquarters will be at Columbia University, and most of the meetings of the sections and of the scientific societies will be held there, though there will be meetings in a number of the educational and scientific institutions of the city.

Each of the separate societies and sections is arranging sessions of interest and importance, and, as the program to be issued at the time of the meeting will doubtless fill more than a hundred pages, it is difficult to select any part for special mention. There is to be a scientific exhibit and conversazione at Columbia University, which is being organized under the charge of some fifteen different committees. There will also be a special chemical exhibit and conversazione at the American Museum of Natural History. It is expected that a joint meeting of physicists and chemists will be held at the City College with a discussion on "The Structure of the Atom and the Constitution of Matter." The four great national engineering societies, which have their headquarters in New York City, plan to hold a special meeting and a reception afterwards to those engaged in work relating to engineering. The Committee of One Hundred on Scientific Research will consider a number of important reports. The American Society of Naturalists will hold a symposium on "Biology and National Existence." Public lectures will be given by Dr. Simon Flexner, director of the Rockefeller Institute for Medical Research, and by Professor A. A. Noyes, of the Massachusetts Institute of Technology, and chairman of the committee of the government on the supply of nitrogen.

These are only a few of the events which will make the meeting of interest quite unparalleled. It is certain that men of science will make special efforts to be present, not only for the interest and profit that they will find in the meeting, but also to contribute their share to the organization of science in the United States, and to impress on the general public the dominant place that science holds in modern civilization.

The meeting will not only be important to those concerned with research,

but also to all those who are interested in any aspect of science, and it is desirable that, following the precedent of the British Association for the Advancement of Science, there may be a large attendance of those who are not professional scientific men. The association admits to membership those who are in sympathy with its aims and who wish to assist in promoting them, even though they are not engaged in scientific work. Information concerning membership may be obtained from the Permanent Secretary, the Smithsonian Institution, Washington, D. C.

SCIENTIFIC ITEMS

WE record with regret the death of Dr. Cleveland Abbe, the distinguished meteorologist, and of Dr. Percival Lowell, of Boston, director of the Lowell Observatory at Flagstaff, Arizona, widely known for his work and theories on the planet Mars.

A MEETING to plan a memorial to the late Sir William Ramsay was held at University College, London, on October 31. After the meeting, the director of the University College Chemical Laboratories, Professor J. Norman Collie, F.R.S., delivered a memorial lecture on "The Scientific Work of Sir William Ramsay."

DR. WILHELM VON WALDEYER, professor of anatomy in the University of Berlin, has been raised to hereditary nobility on the occasion of his eightieth birthday.—The American Academy of Arts and Sciences on November 15 presented the Rumford medals to Mr. Charles Greeley Abbot, of the Smithsonian Institution, for his researches on solar radiation.—The degree of doctor of laws was conferred upon Thomas A. Edison over the telephone by Dr. John H. Finley, president of the University of the State of New York, at the closing session of the institution's fifty-second convocation on October 20. Mr. Edison was in his laboratory at Orange, N. J., while Dr. Finley was in the auditorium of the New York Education Building at Albany.

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The National Academy of Sciences.

Scientific Notes and News.

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Scientific Appointments under the Government, Professor Arthur Gordon Webster. Preparation for Medicine, Dr. Cecil K. Drinker. The Auroral Display of August 26, F. Alex. McDermott, J. E. Hyde, S. Stillman Berry, Wilmer G. Stover, John G. Hessler, H. B. Latimer, R. R. Hudelson, Carl Zapffe, Marcus I. Goldman, Arthur Bevan, W. L. Foster, R. H. Chapman, M. H. Jacobs.

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The Study of Russian in England; Spanish in American Universities; The Ruhleben Camp School.

Educational Notes and News.

Discussion and Correspondence:
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Quotations:
Freedom of Speech in England.

The Penniman Memorial Library of Education, F. P. G.

Educational Research and Statistics:
Comparable Measures of Handwriting, Leroy W. Sackett.

Societies and Meetings:
The National Education Meeting.

SATURDAY, OCTOBER 28, 1916

The Professional School vs. the College in the Training of Secondary Teachers, Will Grant Chambers.

The Inductive-deductive Method of Teaching Physics in Secondary Schools, Dwight W. Lott.

Educational Events:
Municipalities and the Health of Children; The School of Hygiene and Public Health of the Johns Hopkins University; Prizes of the School of Journalism of Columbia University; The University of the State of New York and Mr. Edison.

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Discussion and Correspondence.
Standards of Measuring and the Differentiated Drill, Paul Klapper.

Quotations:
Educational and Federal Tape.

Tests and Examinations, H. L. Terry.

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The Reliability of Spelling Scales, involving a "Deviation Formula" for Correlation, Arthur S. Otis.

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The National Education Association.

SATURDAY, NOVEMBER 4, 1916

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Experimental Methods in Teaching Biology in Secondary Schools, Ernest Carroll Faust.

Is the College "Smoker" a Worthy Social Institution, Herschel T. Manuel.

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The Cost of the College of the City of New York; The Needs of the Cincinnati Public Schools; The Annual Meeting of the American Association of University Professors.

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Discussion and Correspondence:
Fable of the Vocational Expert and the Floor-walker, O. Mores.

Quotations:
The Harvard Tradition; Vocational Training for Bullies

Books and Literature:
Educational Journals.

Results of the Physical Inspection of 18,000 School Children in Virginia, Roy K. Flannagan.

Educational Research and Statistics:
The Reliabilty of Spelling Scales; Arthur S. Otis.

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A Program for the State Care of the Feeble-minded and Epileptic, J. E. Wallace Wallin.

The Teaching of English in Secondary Schools, J. R. Jewell.

The Problem of the College Sorority, Hermione L. Dealey.

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